

S
363.78
A7ROW
2003

Commercial/Governmental Pesticide Applicator

Right-of-Way and Regulatory Weed Training Manual

January 2003

Montana Department
of Agriculture



3 0864 0014 8066 7

DATE DUE

~~MAY 10 2004~~

GAYLORD

PRINTED IN U S A

Right-of-Way Pest Control and Governmental: Regulatory Weed

A Study Manual for Commercial and Governmental Pesticide Applicators

This manual is intended for applicators who apply pesticides to rights-of-way. The right-of-way applicator must demonstrate practical knowledge of a wide variety of environments since a right-of-way can traverse many different terrains, including excessive foliage destruction, and ability to recognize target weeds. The pesticide applicator must also demonstrate practical knowledge of the nature of herbicides and the need for containment of these pesticides within the right-of-way areas and the impact of their application activities in the adjacent areas and communities.

The Appendices in this manual provides applicators with additional reference material. The test will **not** include information from Appendices. The information is only added for your benefit to identify weeds in the field or for reference in the future.

To simplify information, trade named products, and equipment have been mentioned. No endorsement is intended, nor is criticism implied, of similar products or equipment, which are not mentioned.

A special thank you to Susan Kedzie-Webb at Montana State University (MSU) for the illustrations in the General Weed Control section of this manual. Also, acknowledgments to Jim Freeman, Cascade County Weed Coordinator, and Reeves Petroff, MSU Pesticide Education Specialist, for reviewing and your input on this manual; thank you for your help.

Developed by the Montana Department of Agriculture:

Kim Johnson
Training & Development Specialist

Barbra Mullin
State Weed Coordinator

Agricultural Sciences Division, Technical Services Bureau, P.O. Box 200201,
Helena, Montana 59620-0201, (406) 444-5400

Front cover photo: Looking to Crown Butte from Greenfields Bench near Simms. Permission granted from John Lambing to use his photo for the cover.

TABLE OF CONTENTS

GENERAL WEED CONTROL

Introduction.....	1
Sources of Weed Infestations	2
Classification of Weeds	4
Methods of Controlling Weeds	8
Chemical Weed Control.....	12
Environmental Factors Influencing Herbicide Efficacy.....	21
Weeds and Herbicides in the Environment.....	24
Toxicity of Herbicides.....	26
Review Questions	29

RIGHTS-OF-WAY VEGETATION MANAGEMENT

Introduction.....	30
Reasons for Right-of-Way Vegetation Management.....	30
Planning the Control Program for Rights-of-Way	31
Herbicide Control of Rights-of-Way	32
Hazards Within the Right-of-Way.....	34
Alternative Right-of-Way Control Methods	35
Review Questions	37

APPLYING HERBICIDES SAFELY AND ACCURATELY

Introduction.....	38
Types of Application	38
Application Equipment.....	39
Calibration.....	44
Review Questions	51
Appendix A – Noxious Weeds in Montana.....	52
Appendix B – Common Weights and Measures.....	76
Appendix C – Additional Resource Materials	77
Glossary.....	78
References.....	81
Answers to Review Questions	82

GENERAL WEED CONTROL

INTRODUCTION

A weed can be defined as:

- ◆ a plant growing where it is not wanted;
- ◆ a plant out of place; or
- ◆ a plant that is more harmful than beneficial.

Any plant can be a weed in a given circumstance. Kentucky bluegrass that spreads into a flowerbed is a weed; volunteer wheat in a sugar beet field is a weed. A plant is a weed only in terms of its impact on human activities.

Plants commonly referred to as weeds have characteristics that give them the ability to spread and compete well with many cultivated and rangeland plants. Most major weeds have at least several of the following characteristics:

- Continuous seed production for as long as growing conditions permit;
- Unique ways of dispersing and spreading, including vegetative propagation and seed production;
- Ability of seeds to remain dormant in soil for long periods of time;
- Ability to grow under adverse conditions;
- Adaptation to a wide variety of soil and climatic conditions;
- Compete well for soil moisture, nutrients and sunlight; and
- Genetic adaptability, with a wide gene base for competition with beneficial plants.

Economic losses caused by weeds occur every year in Montana. Weeds cause losses to agricultural production by:

- ☐ Decreasing crop yields by removal of water and nutrients from the soil. Many weeds need more water to produce one pound of dry matter than do most of the cereal grains.
- ☐ Reducing the value of agricultural products, such as grains contaminated with weed seeds.
- ☐ Creating an unpleasant odor or off-flavor to milk production when dairy animals eat certain weeds.
- ☐ Requiring extra tillage operations in preparing soil for planting to control weeds.
- ☐ Increasing irrigation costs due to weed growth in and along irrigation ditches. This often results in decreased water flow and added weed control costs.
- ☐ Serving as a source of plant diseases and insect pests. Weeds may also act as alternate hosts for diseases and insect vectors.
- ☐ Being poisonous to humans and livestock.

To produce crops efficiently, it is necessary to reduce the effect of competition by weeds. Although weeds cannot be entirely eliminated, they can be reduced to manageable levels.

SOURCES OF WEED INFESTATIONS

❖ **Humans** are the most effective agent in the dissemination of weeds. Most exotic weeds found in the United States are here because of the movement of people and their products. Weed seeds are moved in hay and seed products, by machinery and vehicles, and in common carriers, such as railroads and trucks hauling cargoes of grain, hay, livestock, and other farm commodities. Movement along travel corridors scatter seeds along rights-of-way and highways, which become sources of infestation to adjoining fields. Use of certified weed free forage and cleaning equipment can help to reduce the spread of weeds.

❖ **Wind** spreads seeds over great distances. Many weed seeds have structural features, which aid their distribution by wind (Figure 1). Some seeds have wings, like those of maple trees, or they may have long, silky hairs or parachutes attached to them such as dandelions or Canada thistle. Tumbleweeds (such as Russian thistle) are especially adapted for seed dispersal when blown along the ground.

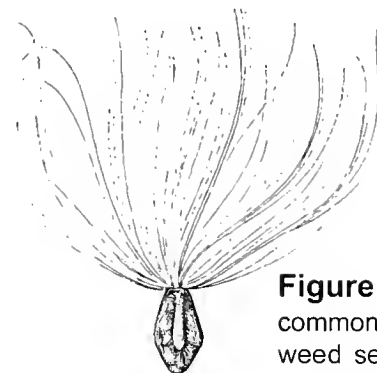
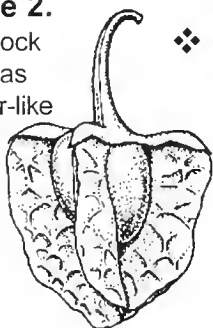


Figure 1.
common milkweed seed is readily carried by the wind.

Figure 2.

curly dock seed has bladder-like floats.

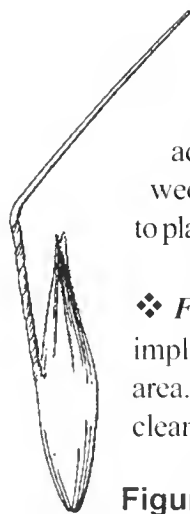


❖ **Water** also effectively spreads seeds. Most weed seeds will float if they fall on the surface of streams, lakes or irrigation canals (Figure 2). Flood waters, running streams, and irrigation water all contribute to spreading weed seeds. Irrigation canals, when first filled, often carry heavy loads of weed seeds downstream where they may be washed ashore or deposited in silt along the way.

❖ **Wild and domestic animals** also aid in the dispersal of seed. The viability of most weed seeds is unaffected by passage through the digestive tracts of animals. Many weeds, such as cocklebur, sandbur, and beggar-ticks, have awns or hooks on the seeds that attach to the hair (Figure 3).



Figure 3.
common cocklebur clings to clothing and animal fur.



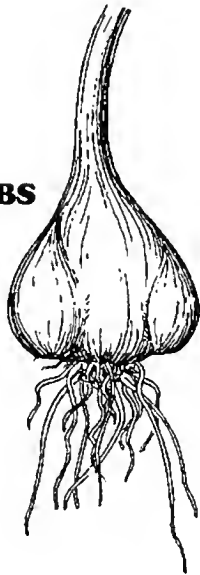
❖ **Planting contaminated** small grain, legumes, or grass seed is another way to spread weeds (Figure 4). Farmers can plant weeds when using non-certified crop seed, often giving the seed a competitive advantage. The planting of certified seed may help prevent the spread of weeds. Mechanical seed cleaning can also remove weed seeds from grain prior to planting.

❖ **Farm machinery** spreads weed seeds, especially in wet weather when seeds stick to muddy implements and vehicles. Plows and cultivators drag roots, rhizomes, tubers or seeds to another area. Combines and hay balers spread weeds from field to field. All farm machinery should be cleaned before moving it from one area to another.

Figure 4. bent awn on the lemma of wild oat seed twists with changes in moisture to bury the seed in the soil.

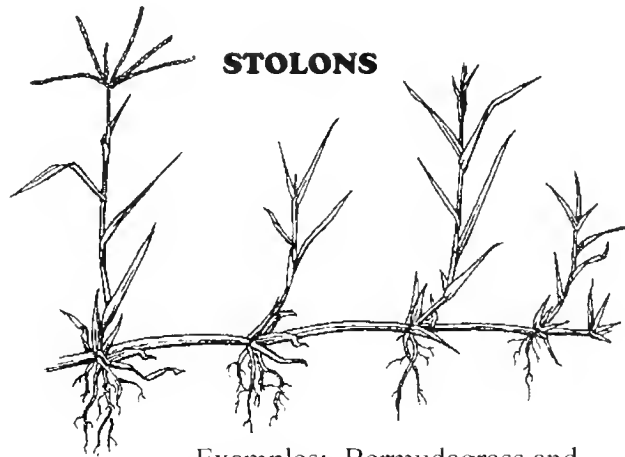
Infestations of perennial weeds are aided by different types of rooting systems. Identifying the root system of a weed is beneficial when selecting a control method. The following are some of the common types of root systems of perennial weeds.

BULBS



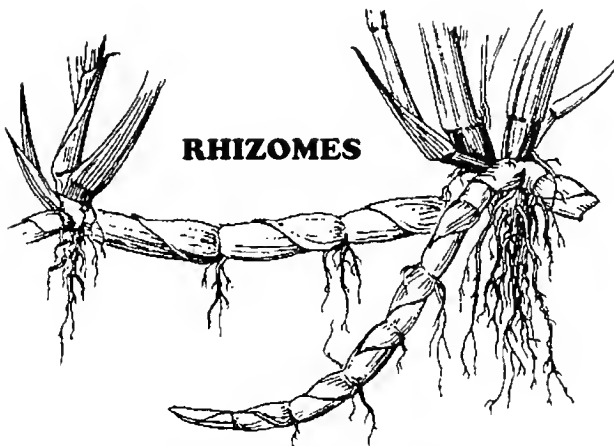
Examples: wild garlic, bulbous bluegrass, and wild onion.

STOLONS



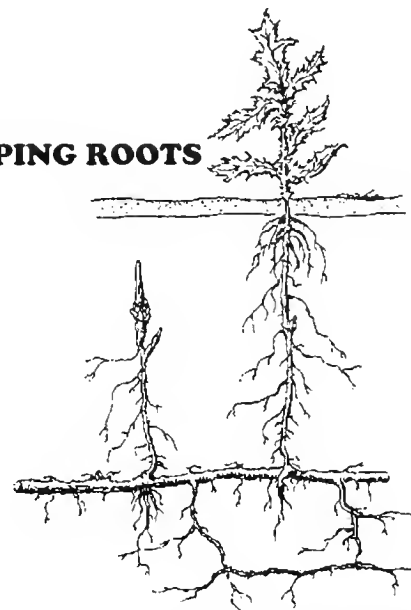
Examples: Bermudagrass and strawberries.

RHIZOMES



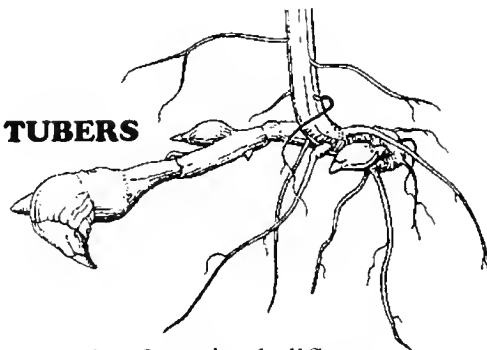
Examples: Saltgrass, sweet pea, and oxeye daisy.

CREEPING ROOTS



Examples: Canada thistle and leafy spurge.

TUBERS



Example: Creeping bellflower

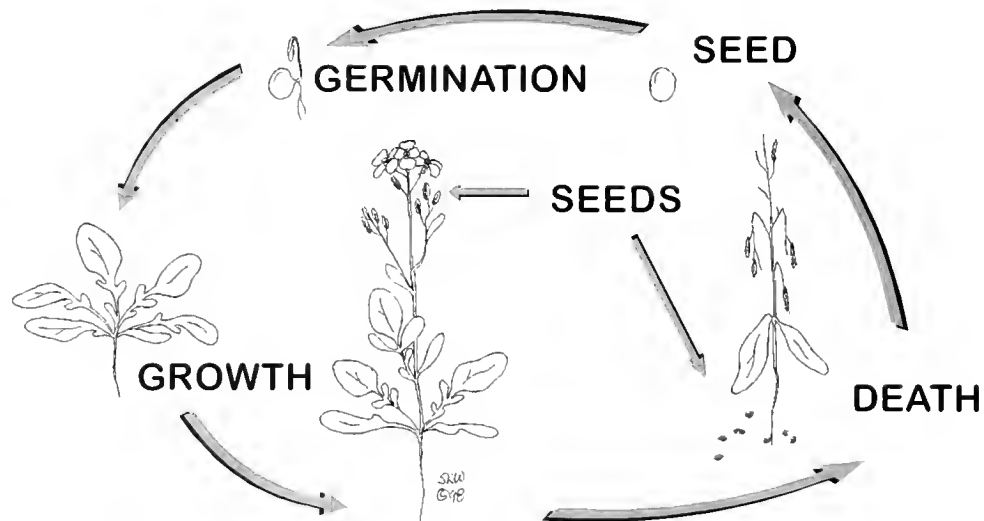
Figure 5. Root types of perennial weeds.

CLASSIFICATION OF WEEDS

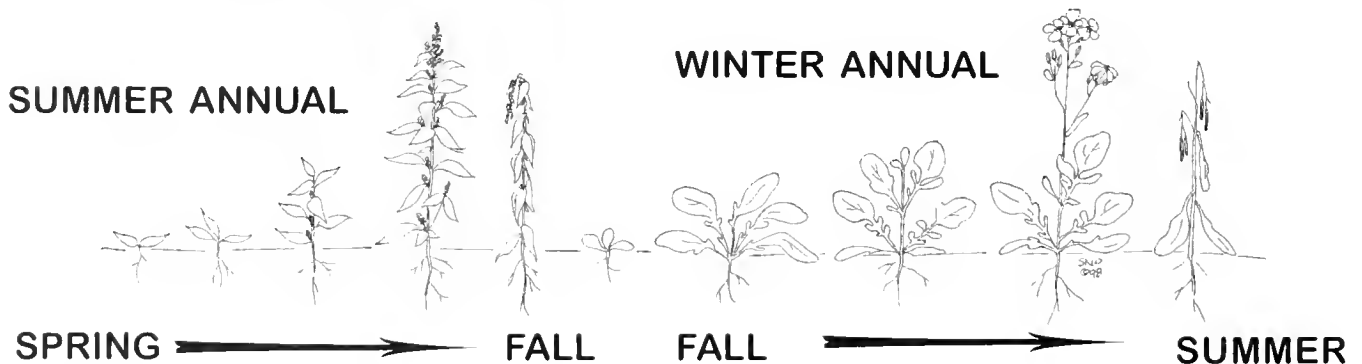
Weeds can be classified by life cycle or plant structure. Identification and control practices are determined in part by understanding these classifications.

■ Life Cycle

The life cycle (or growth habit) of each weed species describes how long each plant lives and timing of development.

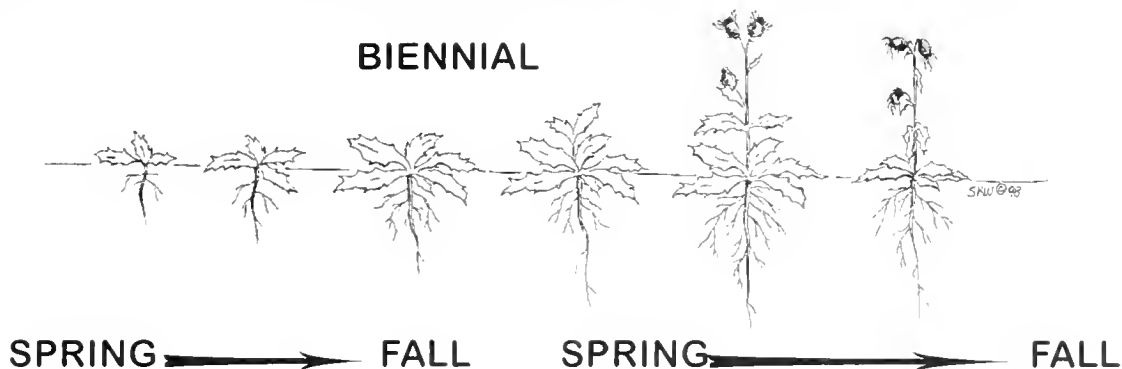


Annuals complete their life cycle from seed to mature plant in less than one year. Summer annual plants germinate in the spring, flower, produce seed in mid to late-summer, and die in the fall. Winter annuals germinate from late summer to early spring, flower, and produce seed in mid to late-spring and die in the summer. Plant growth as a winter or summer annual often depends on geography and climate. Control methods should be taken to prevent seed production. Annual weeds are most susceptible to control in the seedling stage, prior to bolting.



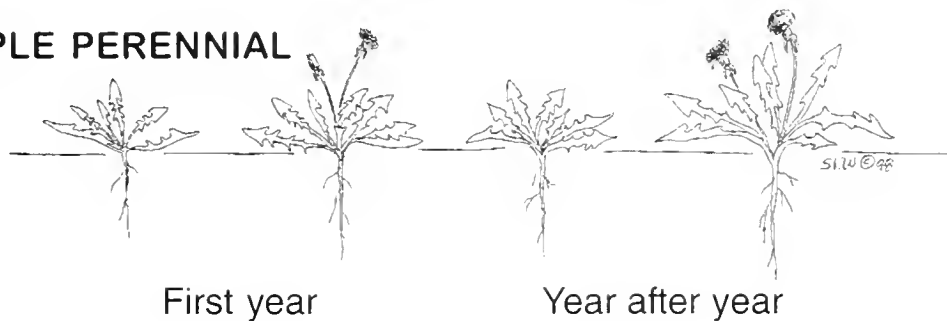
Kochia, lambsquarters, redroot and prostrate pigweed, Russian thistle, green and yellow foxtail, and crabgrass are all examples of summer annuals. Winter annuals include common chickweed, downy brome, field pennycress and many other mustards.

Biennials live for two growing seasons. Seeds germinate in the spring, summer, or fall of the first year and plants overwinter as a basal rosette of leaves with a thick storage root. Plants flower and produce seed the summer of the second year and die in the fall. Common biennials include common mullein, burdock, houndstongue, bull thistle, and musk thistle. Effective control of biennial plants is very similar to control for annuals. Early spring or fall spraying of the rosette is an effective time for control.

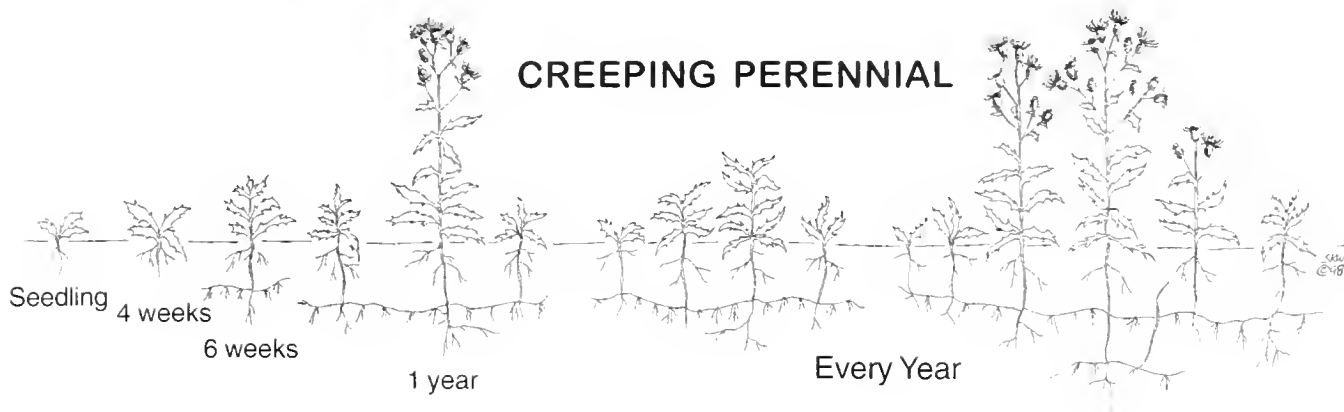


Perennials produce vegetative structures, allowing them to live for more than two years. They reproduce by seed in addition to spreading vegetatively. Simple perennials overwinter by means of a vegetative structure, such as a perennial root with a "crown," but they reproduce almost entirely by seed. Dandelion, curly dock, and spotted knapweed are common examples of simple perennials.

SIMPLE PERENNIAL



Creeping perennials overwinter and produce new, independent plants from vegetative reproductive structures. These structures include rhizomes, tubers, bulbs, stolons, and creeping roots. Most creeping perennials can also reproduce and spread from seeds. Quackgrass, Canada thistle, leafy spurge, and field bindweed are creeping perennials.

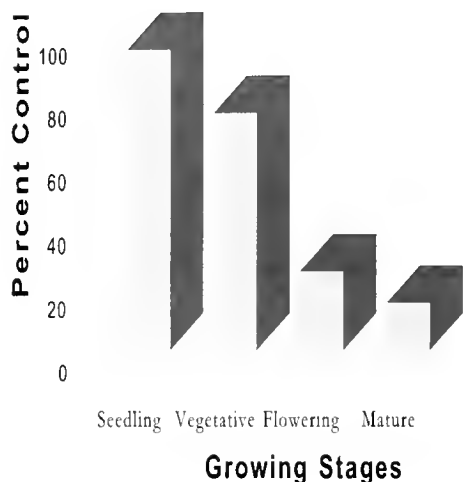


■ Weed Control for Annual, Biennial, and Perennial Weeds

Control of annual and biennial weeds must be accomplished before the plant produces seed.

Control is most effective when the plant is in the seedling stage actively growing, but prior to

Weed Control - Annuals/Biennials

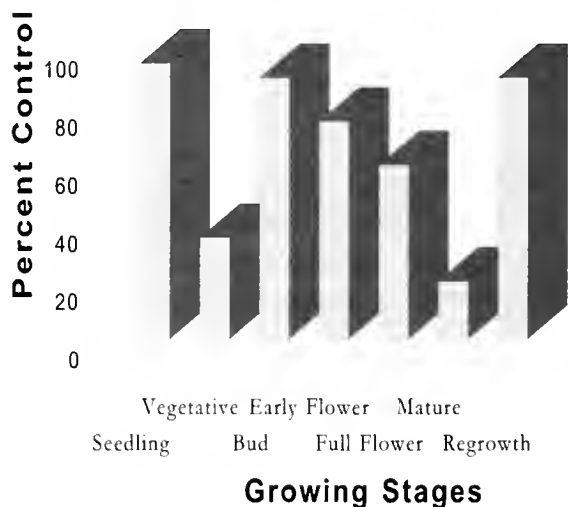


flowering. During the vegetative stage control is possible but more difficult since the plant is putting energy into the production of seeds. Chemical control of annuals during the flowering stage is not feasible because most of the plant's energy is going into seed production. Often flowering annual plants will set viable seed even after control methods are applied if they are applied at a later stage of development. Maturity and seed set completes the annual plant life cycle. Control is not effective at this stage.

Perennial weed control should be aimed at either the seedling or the regrowth stages of

development. Chemical control during the vegetative growth stage is less effective. However, control is more effective at the bud stage than the flowering stage. Control at maturity is not feasible since the above ground portions of the plant die back at this time. Fall treatment of regrowth is very effective because the plant is translocating nutrients to the root system and will also translocate herbicide to control the roots. To achieve effective control of perennials, underground plant parts must be controlled. Long-term management is essential for effective control.

Weed Control - Perennials



■ Plant Structure

Differences in plant structure or morphology are important to recognize. For weed control purposes plants are divided into three main categories—grass, broadleaf, and woody.

Grass plants have one seed leaf (monocot). They typically have parallel leaf venation (Figure 6a), narrow, upright leaves and flower parts in threes or multiples of threes (Figure 6b). Examples include quackgrass, green foxtail, and downy brome.

Broadleaf plants have two seed leaves (dicots). They generally have broad, net-veined leaves (Figure 7a) and flower parts in four, five or multiples thereof (Figure 7b). Examples include kochia, sunflower, and Canada thistle.

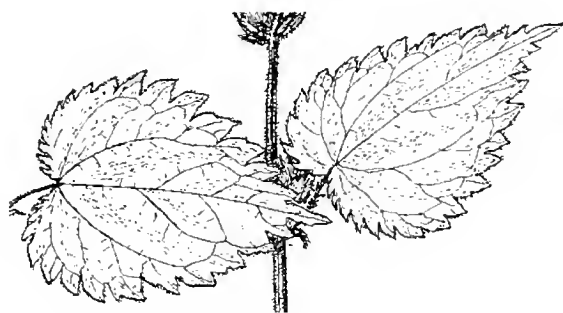


Figure 7a.



Figure 7b.

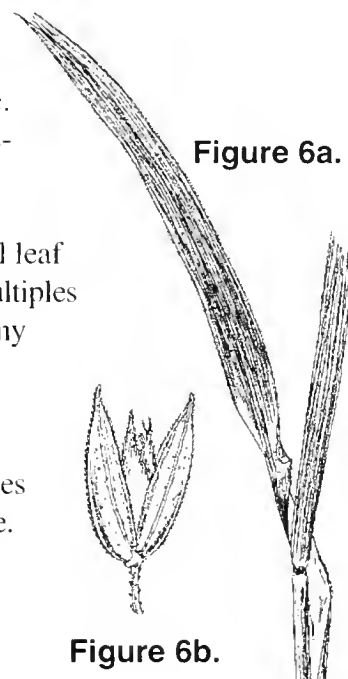


Figure 6a.

Figure 6b.

Woody plants persist from year to year with woody aerial stems and include brush, shrubs, and trees. Brush and shrubs have several stems and are generally less than ten feet tall. Trees have a single stem and are over ten feet tall. Multiflora rose, sagebrush, and salt cedar are examples of woody weed plants (Figure 8).

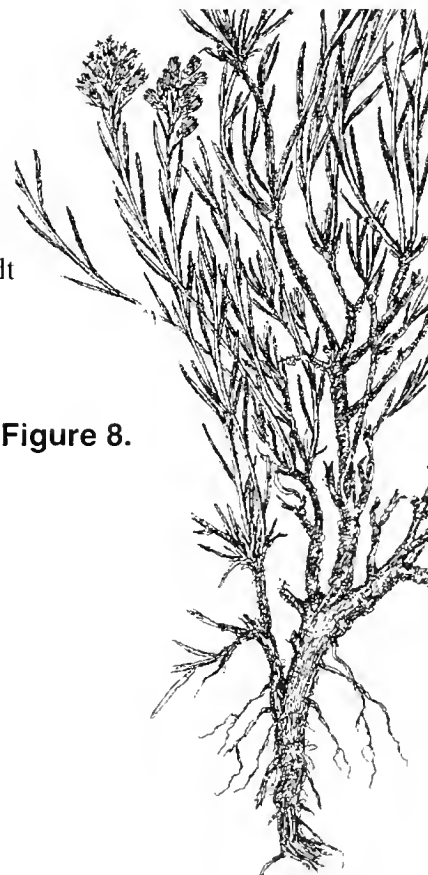


Figure 8.

METHODS OF CONTROLLING WEEDS

For a weed control program to be successful, weeds or undesirable plants must be controlled without damaging crops or desirable plants. Good farming and land management practices should be first in any weed control program. Causes of weed problems should be identified and corrected by implementation of an integrated weed management program, which includes all effective control methods.

The most effective and economical method or combination of methods for weed control depends upon an accurate assessment of the situation.

■ Prevention

Prevention is the most practical and economical method of controlling weeds. Once weeds are established they are difficult and costly to control. Weed seeds may persist for many years as dormant seeds in the soil.

Preventive control measures should be adopted whenever practical. They include: a) the use of clean, certified Noxious Weed Seed Free Forage (NWSFF); b) cleaning all implements, vehicles, and harvesting equipment before moving it from infested areas; c) keeping irrigation ditches, fence rows, roadsides, and other non-crop areas free from weeds; d) not bringing infested soil, hay, straw, or manure into clean areas; e) spot treating small infestations or isolated individual plants; f) not allowing new weeds to set seed or reproduce; and g) quarantining livestock when going from a weed infested area to a clean area.

■ Cultural and Mechanical Control

Cultural and mechanical control includes *cultivation, mowing, mulching, crop competition, and crop rotation*.

Cultivation stimulates the germination of weed seeds by bringing them to the soil surface. These weed seedlings are then easily controlled with a second tillage operation. Tillage is most effective on annual weeds or other weeds in the seedling stage. Repeated tillage operations (every two to three weeks throughout several growing seasons) may control some perennial weeds, such as Canada thistle. Other perennials, such as field bindweed, are spread rather than controlled by cultivation. Hand hoeing can be effective in ornamental settings and some high value crops.

Mowing can be an effective weed control practice under certain conditions. It should be part of an overall crop management program. Mowing controls weeds by preventing seed production, depleting underground food reserves, and by favoring growth of more competitive plants. Mowing must be done prior to pollination and fertilization. Since most plants regenerate, repeated mowing is required for adequate weed control. It is important to remember that repeated mowing may change upright, single stemmed plants into prostrate, several stemmed plants that can still set seed.

Mulches control weeds by excluding light. They are most effective on small areas with high value crops that are already established, such as tomato transplants or flower plants. Mulching material should be thick enough to exclude light, relatively cheap, and easy to work with. Straw, sawdust, wood chips, bark chips, grass clippings, heavy plastic, and paper clippings are all good mulches. Perennial weeds are difficult to control with mulches due to the persistent nature of their vegetative growth. Make sure the mulch does not contain any herbicide residues, because it can affect growth of desirable plants.

Crop competition can be an effective tool. Early spring seeding can allow cereal grains to germinate earlier than weeds. If the crop is established before the weeds germinate, it will often crowd out the weeds. Crops need to establish early and grow rapidly, by taking the nutrients and water the weed would normally use.

"Smother" crops may be valuable in a weed control program. They compete with weeds for water, light, and nutrients. The main competitive crops valued in weed control are crested wheatgrass, sweet clover, sunflower, rape, barley, rye, soybeans, alfalfa, and silage corn. These crops grow quickly, produce an abundance of shade, and can be harvested early enough to permit fall cultivation.

Crop rotation is another method for weed control. Certain crops have their own characteristic weeds, and these weeds tend to accumulate when growth of the same crop is repeated year after year. These repeated plantings favor disease and insect problems resulting in weak, patchy stands, which are easily invaded by weeds. Crop rotation allows use of alternative control methods, including a wider variety of herbicides, to control weeds.

■ **Biological Control**

Biological weed control is the use of a living organism to control weeds. Insects are the most commonly used agent but fish, nematodes, snails, and plant pathogens (fungi, bacteria) offer additional means of controlling plants.

Biological control agents can be useful for suppression of unwanted plants, generally in a non-crop situation. Development of a biocontrol agent is long-term and should be used in conjunction with other weed control methods. Research is necessary to identify host specific agents and anywhere from 5 to 10 different agents are needed to provide economic control of a single weed species. Biological control insect agents are generally too slow acting to be effective in cropland situations. Plant pathogens show more promise in this area and some are registered pesticide products (examples - Mycostop for fungi on field crops and Noyall for *Agrobacterium* on nursery stock).

There are several excellent examples of weed control by insects. The most outstanding is prickly pear cactus control in Australia. Over 60 million acres of infested land were reclaimed using a moth assisted by a scale insect. Another example is found in California and the Pacific Northwest where St. Johnswort (or goatweed) has been reduced on millions of acres to about 1% of its former range by a leaf-feeding beetle.

Some results in Montana using biocontrol agents include:

- ❖ The St. Johnswort beetle, *Chrysolina hyperici*, was first introduced to Montana in 1948, with supplemental releases made over the years. The beetle is cyclical in areas where it is established and has not shown the same dramatic results in Montana as was found in California. This may be because the insect is limited to only one generation per year in the colder Montana climate.
- ❖ A weevil, *Rhinocyllus conicus*, is well established on musk thistle in Montana. It is effective at reducing seed production of this biennial species.
- ❖ A biological control program on spotted knapweed in Montana includes the release of several gallfly species (*Urophora affinis* and *U. quadrifasciata*), a root boring moth (*Agapeta zoegana*), and a root boring weevil (*Cyphocleonus achates*). Research continues on several other root and seed head insects.
- ❖ Dalmatian toadflax has two insects established on it, a foliage eating moth (*Calophasia lunula*) and a seed head beetle (*Brachypterolius pulicarius*). Several root boring moths and seed head weevils were cleared for release in 1996 and research continues on these insects. Some work is also being done on common toadflax biological control agents.
- ❖ A wide range of biological control agents have been introduced on leafy spurge. The most effective to date have been a complex of flea beetles, *Aphthona* species. Research is also targeting plant pathogens that could be used in combination with insect agents.
- ❖ Research on plant pathogens for several weeds continues. The fungus, *Sclerotinia sclerotiorum*, attacks a broad host range of weed species, including Canada thistle and spotted knapweed.
- ❖ Sheep and goats can be used to suppress growth and prevent seed production of leafy spurge and some other weeds in environmentally sensitive areas.

■ Chemical Control

Herbicides are an important weed control tool in Montana. Research over the past few decades has produced increased knowledge and new, safer chemicals for use in weed control. Herbicides will continue to play an important role in weed control in Montana. The *Chemical Weed Control* chapter (page 12) further discusses weed control with chemicals.

■ Integrated Weed Management

Integrated weed management (IWM) is an ecological approach to managing unwanted plants. It is a *systems approach* to weed management that uses all suitable methods in a compatible manner to reduce weed populations to levels below those causing economic or ecological consequences.

Factors to consider *prior* to making a weed management decision include:

- ❖ Weed species present and size of infestation.
- ❖ Environmental conditions: non-target vegetation, soil types, climatic conditions, and water resources.
- ❖ Site restrictions.
- ❖ An understanding of overall management objectives for the area: different land managers and agencies have different goals and restrictions on their activities.
- ❖ Considering the many different control techniques and combinations available when developing a management plan.

All weed management tools must be used to effectively control weed infestations. Annual, biennial, and perennial weeds have certain growth habits that influence the type of control method or methods implemented. Soil type, weather conditions, recreational activity, wildlife or domestic grazing, and future use of the land will influence your choice of weed control methods. Consider all information known about the weed and the site as you develop a long-term management plan for control of a weed infestation.

CHEMICAL WEED CONTROL

Herbicides are effective tools when used properly. Since the early 1950's, thousands of chemicals have been evaluated for effectiveness. Safe, effective herbicides are available for controlling many weeds growing in various environments including cropland, rangeland, gardens, lawns, ditch banks, non-crop areas, and in irrigation, drainage, navigable, and drinking waters. Because of the many factors and principles involved in research on herbicides, information about chemical weed control is rapidly increasing. New recommendations are continually replacing old ones. Be sure to read and follow all label directions from a *current* product label.

■ Selective Herbicides

Chemicals, which can be used to remove certain plant species with little or no effect on other species, are referred to as selective herbicides. Selectivity depends on the amount of chemical used, the application method, the degree of foliage wetting, soil moisture and texture, temperature, and humidity. Since selectivity can be influenced by all of these factors, the same chemical may be either selective or non-selective, depending on the amount used. For example, atrazine used at a high rate is an effective soil sterilant (non-selective) and used at a lower rate is a selective herbicide for weed control in corn.

➔ Foliage applications are treatments made to the leaves of growing plants, usually as a spray or mist.

➤ *Translocated herbicides* move within the plant after the material is absorbed into the tissue. The greatest amount of transport occurs through the vascular system of the plant (phloem and/or xylem). Translocated herbicides may be effective in controlling roots as well as top growth of plants. Selectivity depends on physiological differences of plants. 2,4-D is a commonly used selective, translocated herbicide in Montana.

➤ *Contact herbicides* do not translocate or move within the plant. This group of herbicides controls only the plant or portion of the plant actually contacted by the chemical. In order to obtain effective control, adequate coverage of the foliage is essential. This may be accomplished by using a high volume of carrier or diluent to apply the herbicide. Dinitrophenols and certain petroleum oils are used as selective, contact herbicides.

➔ Soil applications are herbicide treatments applied to the soil. To be effective, the chemical must be carried into the soil by moisture or mechanical incorporation. Selectivity depends on the plant tolerance, soil texture, location of the herbicide in the soil, and difference in growth habit of the crop and the weed. These herbicides are generally translocated in the xylem.

➔ Selectivity can also be determined by timing of applications:

➤ Preplant treatments are made to the soil before the crop is planted. Typical preplant treatments are applied after seed bed preparation but directly before planting the crop. This

type of treatment is considered pre-emergence with respect to weeds if applied prior to weed germination.

➔ Pre-emergence treatments are made to the soil after the crop is planted, but before emergence of the crop or the weeds.

➔ Post-emergence herbicides are applied to the soil after the crop or weeds have germinated and started to grow. Other post-emergence treatments may include:

➤ Pre-harvest herbicide treatment applied before crop harvest to remove weed growth that could interfere with the harvesting operation.

➤ Post-harvest herbicides applied to control weeds present after harvest as part of the weed control program for the next season.

■ **Non-Selective Herbicides**

Herbicides, which are toxic to all plants, may be used to control a wide variety of vegetation in an area. These chemicals can be used to control vegetation in non-cropped areas, such as along fence rows, around electrical power lines and substations, rights-of-way, and storage areas.

➔ Foliage applications are applied to the leaves of growing plants as sprays or mists.

➤ Translocated herbicides move from the foliage to the roots, resulting in control of a wide variety of plant species. There are few herbicides that can be classified as translocated, non-selective. Glyphosate (Roundup) is one good example.

➤ Contact sprays control vegetation at the point of contact. One treatment is usually sufficient to control annual weeds. Perennial plants are not effectively controlled with contact herbicides. Acrolein and paraquat are examples of non-selective contact herbicides.

➔ Soil applications include a wide variety of soil fumigants and soil sterilants that are applied directly to the soil. These are used where it is necessary to remove all plant growth.

➤ Soil fumigants are non-selective chemicals that are most often used to control all plant growth, as well as other soil organisms, before planting a desirable species. They function as a vapor or gas, which diffuses through the soil and has a short life in the soil. The treated area may be replanted, usually within a month or less.

➤ Soil sterilants are chemicals that control all green plants for a period of up to two or more years. They are classified as:

⌚ Temporary sterilants, which control plant life for four months or less.

⌚ Semi-permanent sterilants, which control all plant life for four months to two years.

⌚ Permanent sterilants, which persist in the soil for longer than two years.

The length of time the herbicide residue remains depends on the herbicide used, the rate of application, and the soil moisture and texture.

■ **Basics of Herbicide Selectivity**

It is important to understand how herbicides control plants, why a herbicide is phytotoxic to one species and not another, and how herbicides can be used to best accomplish the results desired.

The most important factors that affect herbicide selectivity are: 1) structural differences in plants, 2) differences in absorption, 3) differences in translocation, 4) physiological differences, and 5) herbicide concentration. Combinations of these factors can be used to improve herbicide selectivity.

➔ Structural differences among plants permit selective applications. The narrow, upright leaves of a cereal plant lack the exposed leaf surfaces of a broadleaf plant. Water droplets can stick only to a small portion of an upright leaf surface. On the other hand, a broadleaf plant has a wide leaf surface, which extends parallel to the ground and will hold more spray, causing the plant to be more affected by the herbicide. Another important structural difference is the location of the growing point of the plant. The growing point of many grasses is protected because it is located at the base of the plant. Contact sprays may injure the leaves of the grass plant, but not contact the growing point. Broadleaf plants have exposed growing points at the tips of the shoots and in the leaf axis. The growing point is, therefore, more accessible to the herbicide.

Waxiness (cuticle) or hairiness (pubescence) of a plant may prevent spray droplets from adhering to the leaf. If the chemical droplet adheres to the leaf hairs without contacting the leaf surface, it will not be absorbed. On the other hand, hairs may collect and hold greater amounts of droplets, preventing the spray from running off the leaf surface. Waxy leaves may require use of an additive with the herbicide to dissolve the waxy layer and allow contact with the leaf surface.

➔ *Absorption* is the movement of a material into the plant from an external source. Some plant surfaces absorb herbicides quickly; other surfaces may absorb the chemical slowly, if at all. Parts of the plant leaf surface, the cuticle and the stomate, account for differences in absorption.

➤ The *cuticle* is a waxy layer or thin film on the leaf surface, which retards the movement of water and gases (oxygen and carbon dioxide) into and out of the leaf. The cuticle varies in thickness in different plants and can vary within the same plant exposed to different environmental conditions. Shaded plants often have thinner cuticles than plants grown in the sun, and young leaves usually have thinner cuticles than older leaves. A herbicide must penetrate the cuticle layer and cell wall. High temperature and low humidity usually result in poor cuticle penetration.

- A plant leaf is perforated by small openings or pores called *stomates*; these open into the intercellular spaces within the leaf. The number and distribution of the stomates vary from plant to plant. The stomatal opening can be an effective port of entry for the herbicide if they are open at the time of application. This is why some foliar applied sprays are more effective when applied in the early morning or late evening when there is less sunlight and the stomates are more likely to be open. Stomatal penetration cannot occur unless the surface tension of the spray solution is significantly reduced by the use of wetting agents.

- ➔ After the herbicide is absorbed, it must be translocated within the plant to the site of action. There are two tissue systems in which a herbicide may move within the plant: the *phloem*, which conducts food from the plant leaf to the stem and roots; and the *xylem*, which conducts water and nutrients from the roots to the stem and leaves. Herbicides move through these conducting tissues to other parts of the plant.
 - *Phloem tissues* are composed of living cells. It is important, therefore, not to kill the stem and leaf tissues too quickly. Rapid foliage kill will result in poor transport and poor root control. Movement in phloem will be toward the roots during maturation of the plant and near budding. This indicates the importance of proper timing of a herbicide application, especially for the control of perennial weeds. It is necessary to apply a translocated herbicide when a perennial is storing up root reserves. Most growth regulators including 2,4-D, as well as dicamba and glyphosate, move readily in phloem tissue.
 - *Xylem tissue* of a plant is made up of non-living cells. It is the water conducting, transpiration system in the plant and movement is only from the roots upward to leaf and shoot tips. Translocation of chemicals applied to either the roots or foliage will only move toward the leaf tip. Atrazine, metribuzin, and diuron are examples of xylem conducted herbicides.

- ➔ The physiological differences between plants also affect herbicidal toxicity. Differences in enzyme systems, responses to pH changes, cell metabolism, cell permeability, variations in chemical constituents, and polarities may all influence the selectivity of a herbicide to plants. Any herbicide that stimulates or blocks certain biochemical processes in a plant can affect the plant's growth.

Enzyme reactions may be blocked in one plant species, but not in another, by the same chemical. The following are examples of enzyme reactions: 2,4-DB converted to 2,4-D by certain plants and corn has enzymes that can degrade triazine herbicides into harmless compounds.

- ➔ The rate of application or concentration may determine whether a herbicide inhibits or stimulates plant growth. Low concentrations of 2,4-D can act as a growth hormone and increase the rate of respiration and cell division, resulting in stimulated plant growth. At higher rates, growth is excessive and results in death of the plant.

■ **Herbicide Formulations**

Almost all herbicides must be combined with a liquid or solid carrier to uniformly distribute them during application. The formulation of a chemical is the manner in which the active ingredient and the carrier are mixed. Proper formulation of agricultural chemicals increases their effectiveness. Inert ingredients make the herbicide easier to handle, less likely to settle out or degrade during storage, and may minimize the hazard of handling the chemical. The way the herbicide is formulated may change its chemical characteristics including solubility, volatility, and toxicity to plants.

Common types of formulations are classified as follows:

➔ *Liquid Formulations*

- Emulsifiable concentrates (EC) are nonpolar (oily) liquids containing emulsifiers, a substance promoting the suspension of one liquid in another. The active ingredient is not soluble in water, but is dispersed in water to form emulsions (droplets of oil surrounded by water). Agitation is usually required to prevent separation.
- Solution(s) are herbicides (liquid or powder) that are directly and rapidly soluble in the carrier liquid. These require no agitation once dissolved in solution. Often they need a surfactant for maximum activity.
- A suspension consists of a finely ground wettable powder (WP) dispersed in a liquid. Wettable powders are used if a solid concentrate is preferable to a liquid or if the solubility of a herbicide is so limited that it is impossible to formulate an economical solution or emulsifiable concentrate. These herbicides are nearly insoluble in water or oil, but may be dispersed in them by forming a slurry, adding it to the carrier and using constant agitation.
- Water dispersible liquids and granules are often referred to as flowables (F) or dry flowables (DF). These formulations readily disperse in the herbicide carrier. They require a moderate amount of agitation. Both liquids and granules can be added to water without first making a slurry. Water dispersible granules pour cleanly from the container, giving them handling advantages over dispersible liquids and wettable powders.

➔ *Dry Formulations*

- Granule formulations have been impregnated into coarsely ground carriers, such as clay or vermiculite, and formed into small pellets, generally less than 10 mm in size. These chemicals are used directly from the bag, but require special application equipment and usually require soil incorporation to be effective.
- Pellets are discrete particles usually larger than 10 mm. They are frequently used for spot treatments.
- Dusts are finely ground chemicals that may or may not be mixed with diluents. Their use is limited because of the hazard of drift and the high cost of the herbicide.

■ Spray Additives

Adjuvants or spray additives are often used to enhance herbicidal performance or handling. They include surfactants, anti-foaming agents, compatibility agents, crop oils, crop oil concentrates, and drift control agents.

➔ *Surfactants* (surface-active agents) bind two or more incompatible phases, such as water and oil, in more intimate contact by modifying forces between them. A surfactant is any material that affects the surface properties of spray solutions and includes wetting agents, emulsifiers, dispersing agents, detergents, and stickers.

➤ Wetting agents are materials used to increase a liquid's ability to moisten a solid. They lower the surface tension, bringing the liquid into closer contact with the solid. Wetting agents increase or decrease the effectiveness of herbicide sprays; they may also reduce selectivity, especially if selectivity depends on selective wetting or selective absorption.

➤ An emulsifier is a material used to disperse one liquid in another. An emulsion is one liquid dispersed in another, each maintaining its original identity.

➤ Dispersing agents reduce cohesion between particles. They are materials used to disperse the particles of a solid in a liquid. Some dispersing agents also act as wetting agents, but others have little or no effect on surface tension. Some wetting agents and dispersing agents are not compatible and interfere with each other if used together.

➤ Detergents are used to remove dirt or grime. They are usually wetting agents and surface active. Many common detergents have been used with herbicides as wetting agents and emulsifiers. Antifoaming agents can be used to reduce foaming in a sprayer system so pumps and nozzles can operate properly.

➤ A sticker is designed to hold the active ingredient on the sprayed surface.

➤ A penetration agent is any substance that assists plant absorption of a herbicide. Such substances may dissolve the waxy cuticle or fatty portion of the cell wall or membrane of the plant to allow more rapid penetration.

➤ Anticaking agents are used to prevent solid herbicide formulations from forming aggregates.

Surfactants are classified as ionic and nonionic, depending on their disassociation in water. Nonionic agents have no particle charge, while ionic agents have either a positive or negative charge.

Nonionic surfactants are classed as nonelectrolytes and are usually chemically inactive in the presence of usual salts. They can be mixed with most herbicides and still remain chemically inactive. *Ionic* surfactants ionize in an aqueous medium. These agents can be used to unite oil or water soluble properties of a molecule and reduce water surface tension.

- ➔ Compatibility agents aid suspension of herbicides when they are combined in tank mixes with other pesticides, herbicides, or fertilizers. They are used frequently when a liquid fertilizer is the carrier solution.
- ➔ Crop oil and crop oil concentrates. There are two types of crop oils; the true crop oils that are derivatives of canola, corn, etc. and tend not to be as phytotoxic as the synthetic crop oils that are petroleum distillate derivatives. Crop oils are added to water solutions to enhance herbicide foliar activity.
- ➔ Drift control agents reduce the fine particles in a spray pattern that are primarily responsible for herbicide drift and nontarget injury.

All adjuvants should be used in accordance with label directions and chosen only from those proven effective for herbicide applications. Refer to the manufacturer's recommendations and herbicide label recommendations.

■ **Mixtures of Herbicides with Other Pesticides or Fertilizers**

The use of herbicides mixed with other pesticides or with fertilizers is an advantage to farmers by saving time, labor, and the number of trips across fields. Yields can be as good with combination applications as with split applications. Research has confirmed that herbicides applied with some fertilizers can perform as well as with single applications.

Most herbicides are specific and their activity is not the same toward all weeds. For example, trifluralin does not control nightshade species in beans and alachlor is weak on kochia. Because of these and other limitations of single herbicides, interest in mixing herbicides to control a broader spectrum of weeds and provide more consistent control over a wide range of climatic conditions has increased. Combinations can also lower the rates of application necessary and thus decrease crop injury and soil persistence.

There is a possibility of synergistic effects resulting in increased herbicidal activity beyond that of either single chemical. There can also be an antagonistic effect in which injury to the weeds may be less than with either chemical alone. There are limitations and concerns about mixing chemicals without research data. Herbicides should not be mixed with other herbicides or fertilizers unless the combination has been thoroughly researched and is registered for use.

The following factors should be considered before mixing herbicides with any pesticide or fertilizer:

- ➔ Pesticides vary greatly in their physical and chemical compatibility with each other and with fertilizers. In many cases there can be a physical inactivation when two formulations precipitate out of solution. There can also be a chemical reaction and inactivation between two incompatible products. A small, scale test for physical compatibility is recommended if the applicator has no previous experience with the mixture. Mix proper concentrations of the chemicals to be tested with the proper amount of carrier in a wide-mouth, one-quart jar. Agitate well and let stand over night. Check for precipitate in the bottom of the jar. This will only indicate physical compatibility - not possible chemical incompatibility and synergistic or antagonistic effects.
- ➔ Agitation (keeping a herbicide uniformly dispersed in a mixture) is also important. It is a general rule to never add a wettable powder to the surface of a full or nearly full tank of liquid and slurry the powder before adding it to the tank.
- ➔ Optimum placement of each product may rule out a combination application. Some fertilizers are incorporated fairly deep while many herbicides need shallow incorporation or are left on the soil surface. Some fertilizers are broadcast while others should be soil incorporated. Appropriate placement of each herbicide must be considered separately. Correct placement of the herbicide should have preference.
- ➔ The applicator must determine if the timing of the application, placement, and distribution of each component of the mixture is similar enough to be applied as a mixture.

Often the application time is different for herbicides and fertilizers. Optimum time for herbicide application is usually just before planting, during planting, or soon after planting. Fertilizers are often applied in the fall or early spring. Again, correct timing should have preference.

■ **Herbicide Application**

Ideal application techniques provide uniform distribution of the herbicide on plant foliage or in the soil. Chemical formulation will usually dictate what type of equipment should be used for application.

- ➔ Spraying is the most common method of application. A spray may be defined as liquid discharged so it subdivides into particles that scatter and fall as dispersed droplets. Spraying permits reasonably uniform application and allows accurate direction of the herbicide to a given area, such as foliage or soil. Sprays may be applied from sprinkler cans, hand pumps, compressed air, and power sprayers. Most available herbicides can be sprayed using a water carrier. Water acidity or alkalinity can chemically affect a herbicide and inactivate it. If this is a concern water pH should be tested.
- ➔ Granules are spread by hand or with special mechanical spreaders designed specifically for such use. Applicators may broadcast the granules evenly over the entire spreader width or

in bands over the crop row. These applicators are generally refined fertilizer applicators or seeders and may include equipment for soil incorporation. Granular herbicides have the advantage of being less bulky since they are premixed and eliminate the need to handle water. The equipment is also less complex. The major disadvantages include lack of uniform herbicide distribution and lack of versatility of equipment. Granulars are often more expensive than sprays.

➔ Fumigants are injected into the soil by both hand and power-operated equipment. The utility of this equipment is obviously limited and cost of application is generally very high. Fumigants demand caution in handling since they are highly volatile and extremely toxic. Usually airtight covers must be laid down over treated areas to prevent escape of vapors. Fumigants will give increased control for soil insects, nematodes, and some plant diseases, as well as weeds.

■ **Plant Growth Regulators**

Plant growth regulators (PGRs) are used to regulate or modify the growth of plants. A plant is made up of many cells with specialized functions. Plant growth regulators can change or regulate the development of these cells. PGRs are used to thin apples, control the height of turf grass, control the height of some floral potted plants, promote dense growth of ornamentals, and stimulate rooting. They are used in minute amounts to change, speed up, stop, retard, or in some way influence vegetative or reproductive growth of a plant.

Maleic hydrazide is a plant growth regulator that restricts development of new growth by preventing further cell division. The older cells, although affected by the chemical, may continue to grow through cell division, but prevents cell maturity. Maleic hydrazide is also sometimes used to control suckers.

Potted plants, such as chrysanthemums, Easter lilies, and poinsettias, may grow too tall. Plant height can be regulated with growth regulators that are applied at the proper stage of growth. Plant growth regulators are used to control vegetative growth and promote earlier flowering and development in some species. Some are used to control shoot tips, resulting in additional branching. Plant growth regulators are used on apples and peaches to increase fruit color and may result in earlier and more uniform ripening of fruit. They can also be used to thin the fruit, widen branch angles, produce more flower buds, prevent fruit drop, increase fruit firmness, reduce fruit cracking, reduce storage problems, and encourage more uniform fruit bearing.

Rooting hormones are used to increase the development of roots and speed up rooting of certain plants. Gibberellic acid stimulates plant growth. This is sometimes used to initiate uniform sprouting of seed potatoes and increase the size of sweet cherries.

ENVIRONMENTAL FACTORS INFLUENCING HERBICIDE EFFICACY

Rainfall, soil type and conditions, temperature, light, and crop type all have a direct effect on herbicide efficacy. Understanding these effects aids in proper herbicide use, improves weed control, and reduces crop injury.

■ Rainfall

Time of germination of crop and weed seeds, their growth rate, and stage of growth at spraying time are partially determined by the incidence and amount of rain. Rain a few days before spraying can improve penetration of a herbicide into a plant by increasing the wettability of the leaf. Rain may mechanically damage the wax structure of the leaf surface, making the plant more susceptible to chemical absorption. The wax, cuticle, and hair on the leaf surface, the angle of the leaf, and the humidity of the air help to determine how much chemical is retained and absorbed.

Rain, during or closely following application of a herbicide, may wash the spray from the leaves and reduce its effectiveness. The degree of leaf washing depends, not only on the quantity of rain and its intensity, but also on the structure of the crop-weed stand. The leaf penetration of herbicides ceases, or is reduced, a few hours after application when droplets have dried. Traces of rain, dew, or fog after spraying increase penetration.

The relative humidity at the time of chemical application and for many days after application, will affect the degree of weed control. Moist air increases herbicide penetration, absorption, and translocation within the weed. Crop density and stand height also affects the relative humidity in the area.

■ Soil

Soil composition and moisture influences herbicide persistence. The length of time that a herbicide remains active or persists in the soil influences the length of time weed control can be expected. It also determines the length of time until a sensitive crop can be grown in a treated area. Persistence is a desirable or undesirable characteristic depending on the crops to be grown or the weeds to be controlled.

➔ Soil moisture, rainfall, or irrigation is essential in a successful weed control program. Sufficient moisture stimulates uniform germination of weed seeds and vigorous growth of the plant. Chemical application under these conditions is more likely to succeed than when the soil is dry prior to treatment.

Dry conditions cause uneven germination of the weeds and delay crop development. As a result, proper timing of post-emergence herbicides is difficult. Weeds will be uneven in size and difficult to control and the crop may be at a stage where injury could occur.

Water stress can affect herbicide retention, penetration, and absorption. Leaves grown under water stress have more cuticle per unit area and a lower wettability than leaves from plants not under stress.

➔ Factors having the greatest effect on herbicide soil residues are leaching, fixation on soil particles, chemical and microbial decomposition, and volatilization.

➤ Leaching is the movement of a herbicide through the soil. The extent to which a chemical is leached depends upon its solubility in water, the amount of water passed through the soil, and the adsorptive relationship between the herbicide and the soil. In general, water soluble herbicides and those not readily attached to soil particles are most readily leached.

➤ Fixation or adsorption of herbicides on soil particles reduces the concentration available in soil water. Soils heavy in organic matter or clay type soils tend to hold the herbicide for a longer period of time, thus slowing the rate of chemical release and either prolonging or lessening its effectiveness, depending on the rate of application.

➤ Chemical decomposition involving reactions such as oxidation, reduction, and hydrolysis, destroys most herbicides and activates others. Very little is known about the effects of soil chemistry on herbicides.

➤ Microorganisms in the soil are responsible for much of herbicide decomposition. Algae, fungi, and bacteria need food for energy and growth. Organic compounds in the soil, including herbicides, provide most of this food. Warm, moist, well-aerated, fertile soils are most favorable to soil microbes and under ideal conditions will quickly decompose most organic herbicides. The effect of herbicides on the microbe population is minor when used at normal field rates.

➤ Volatilization causes herbicide loss to the atmosphere as a gas. All chemicals have a vapor pressure and this usually increases as the temperature rises. The gases formed may be toxic to plants and may drift to susceptible plants. Water will leach the herbicide into the soil and aid soil adsorption. Once adsorbed, loss by volatilization is greatly reduced.

■ Temperature

Temperature conditions influence germination and growth rates of weeds and crops. Temperatures at the time of spraying are important in determining the plant response to the herbicide. High temperature generally increases the activity of herbicides. There is also an increase in translocation at higher temperatures. In general, high temperatures before and after spraying appear to increase weed susceptibility and mortality, but extremely high temperatures may reduce penetration by causing wilting, closing of leaf openings, and evaporation of the spray drops. High temperature also increases the incidence of herbicide drift or volatilization.

Temperature changes produce metabolic differences in some plants, which affect their susceptibility to herbicides. A plant at a low temperature may not produce a particular metabolic substance, which is necessary to obtain a response to a herbicide. Tests indicate this occurs in plants, such as big sagebrush or rabbitbrush, which do not respond to 2,4-D at low temperatures and low moisture. Temperature also has an effect on direction of movement in a plant.

Temperatures have important effects on the dissipation of herbicides from plant foliage or from soil. Some esters of 2,4-D evaporate readily. When such herbicides are applied at high temperatures their loss as vapors is quite rapid. These losses reduce herbicide effectiveness.

■ Light

Light is essential for optimum plant growth. Weed growth in a crop situation can be affected by shading. Growth response to shading will vary among species.

The leaf surface may be affected by light intensity. Leaves have less cuticle, cutin, and wax when grown in the shade. This might lead to differences in susceptibility of the leaf wax structure to weathering and abrasion. The leaf wettability increases when plants are grown in the shade.

Light (sunlight and ultraviolet light) can cause decomposition of some herbicides also. It is difficult to determine the relative importance of this phenomenon in the field where the herbicide may be lost through other factors, but it can be demonstrated under laboratory conditions. Loss from photodecomposition of such herbicides as the dinitroanilines when not soil incorporated can be important in a field situation.

WEEDS AND HERBICIDES IN THE ENVIRONMENT

All weed control practices alter the environment whether it is hand pulling, hoeing, cultivating, burning, chemical application, or use of biological control agents. Our concern is that the change in the environment does not produce harmful side effects to non-target plants, soil, water, animals, or humans.

■ Drift and Volatility of Herbicides

Herbicides, if used correctly, can be useful tools in land management programs, but if used incorrectly, they can create serious problems. With greater emphasis on a healthy environment, it is important that herbicides be applied in a proper manner. People involved in application must understand such things as spray drift, spray volatility, and taking precautions to prevent damage to non-target organisms.

➔ Spray drift is the movement of spray particles out of an intended area. Drift is dependent mainly on 1) droplet size, 2) wind velocity, and 3) height above the ground. A water droplet 5 microns in diameter can drift over three miles, falling 10 feet, when the wind velocity is 3 mph. Certain atmospheric conditions associated with high temperatures can cause thermal updrafts-lifting spray droplets in the air and depositing them a considerable distance away.

In the last few years, several methods of reducing drift have been developed. The most advertised method has been invert emulsions. Esters of 2,4-D make a milk-like "oil-in-water" emulsion that sprays like water. If the emulsion is reversed (inverted) to a "water-in-oil" liquid and, with proper spray equipment, the mixture can be sprayed in large droplets. Other methods for reducing drift include using shields, placing more nozzles on the boom, reducing pressures, and use of drift control additives.

➔ A considerable body of literature exists on the volatility of esters of 2,4-D and related compounds. Volatilization is the tendency of a sprayed material to vaporize after it has hit the soil or plant surface. Because of the small amount of material involved, volatility is usually a hazard only when extremely sensitive crops are nearby. For example, cotton is sensitive to as little as 1/1000 pound per acre of 2,4-D. Tomatoes and some ornamentals are also sensitive to 2,4-D damage.

Volatility can be controlled only by reducing the tendency of the chemical to vaporize. The major herbicide, which causes economic crop damage due to volatility is 2,4-D. The crystals of 2,4-D acid and amines of 2,4-D are not volatile while ester formulations have varying degrees of volatility depending on the type of alcohol used to make the ester. Butyl, ethyl, and propyl esters of 2,4-D are very volatile and should not be used if sensitive crops are growing in the area. Iso-octyl and propylene-glycol are examples of ester formulations, which are classified as low volatile and do not vaporize easily. These esters are about 10 to 20 times less volatile. However, all forms of amines are less volatile than any of the ester forms. In the last few years, attempts to reduce volatility have resulted in the formulation of 2,4-D acid in oil mixtures and more recently, in oil soluble amine formulations. To spray an amine with oil will usually increase its effectiveness to equal that of an ester formulation.

■ **Protection of Non-Target Plants**

By far the greatest hazard associated with herbicides is the phytotoxic effect on non-target plants caused by incorrect or inaccurate application.

Examples of hazards that need to be avoided are:

- ◆ Spray drift, in either particle or vapor form, deposited on non-target plant foliage;
- ◆ Soil contamination resulting in root uptake by non-target plants;
- ◆ Excessive soil persistence causing injury to subsequent crops; or
- ◆ Sprayer contamination.

Because of the effects that herbicides produce on plants, their presence can be readily detected in terms of characteristic symptoms or death.

Spray drift of certain soil applied or persistent non-crop herbicides can injure susceptible non-target plants (beans, sugar beets) even when the drift occurs before seeding the crop.

Plant growth regulating (hormone-like) herbicides present the greatest visible hazard to non-target broadleaf plants. Conversion to a vapor associated with temperatures of about 90 degrees and higher can be a hazard with low volatile ester forms of 2,4-D and related herbicides. High volatile 2,4-D esters present an extreme vapor hazard and their use should be confined to areas where sensitive crops are not in close proximity.

All of the herbicides listed below are plant growth regulators and can promote abnormal plant growth when found in trace amounts. Once these herbicides are used, adequate decontamination of sprayers poses a problem, especially if the sprayer is multipurpose and must be used for application of other pesticides. Emulsifiable (oil-soluble) forms, such as esters and oil soluble amines are more difficult to clean from spray equipment than the water-soluble metallic and amine salts.

There are several suggested decontamination procedures in the *Basic Pesticide Manual*. Using the right procedure and with enough effort, decontamination can be accomplished. When using sprayers for multiple use applications, extreme care should be exercised.

Herbicides that May Present a Drift or Equipment Contamination Problem	
2,4-D	Picloram
MCPA	Dicamba
MCPB	

Remember that all herbicides are subject to drift under certain conditions. Good judgment should be used when applying any herbicide. Remember to follow all label directions!

TOXICITY OF HERBICIDES

Any herbicide, in large enough doses, can pose a health hazard. However, at recommended rates, most herbicides are relatively non-toxic to humans and the environment. Herbicides, as with all pesticides, should be used only according to label directions. The information provided on the label is for the safety of the applicator as well as for anyone in the area and label directions, including use of safety equipment, should be carefully followed.

■ LD₅₀ Values

Toxicity is the capacity of a substance to produce injury. The toxic action of greatest concern is the lethal dosage (LD) or the amount that will kill. Toxicity of a given substance varies with species, age, sex, and nutritional status of the test animal as well as with the route of administration (internal or dermal).

The basis used to express acute toxicity of a pesticide is LD₅₀, which is the average lethal dosage (LD) per unit of body weight required to kill one-half (50%) of a population of test animals. The usual test animals are white rats, but may be mice, rabbits, and in some cases, dogs. The most common LD₅₀ is the acute oral toxicity, that is, the single internal dosage necessary to kill half the population of the test animals.

The acute oral toxicity has limitations because it represents only the immediate toxicity of an internal dosage and not the chronic and cumulative effects or any skin absorption or irritation. Few herbicides are absorbed rapidly through the skin and most herbicides do not accumulate in the body to a toxic level. However, some do cause skin irritation. LD₅₀ values are expressed in terms of milligrams of chemical per kilogram of body weight (mg/kg). Some conversion factors to convert to common terms are:

1 ounce = 28.38 grams = 28,380 milligrams

1 kilogram = 1,000 grams = 2.2 pounds

Therefore, an LD₅₀ of 1,000 mg/kg would be 3 ounces of material per 180 pounds of body weight, while LD₅₀ values of 100 would be 0.30 ounces per 180 pounds. Since toxicities depend on body weight, it would take only one-third of this amount to kill a 60-pound child and five times as much to kill a 900-pound animal.

LD₅₀ values are expressed on active ingredient. If a material is only 50 percent active ingredient, it would take two parts of the material to make one part of the active ingredient. In some cases, adjuvants mixed with the active ingredient for formulating a pesticide may cause toxicity to differ from that of the active ingredient alone. For example, the LD₅₀ of 2,4-D acid is 320 mg/kg, while that of the ester formulation is 500 to 600 mg/kg.


The acute oral LD₅₀ values for the active ingredient of some common herbicides are given in Table 1.1. Remember, the lower the LD₅₀ value, the greater the toxicity. A common standard for comparison might be aspirin, which has an LD₅₀ value of 1,200 mg/kg.

Table 1.1 The lower the LD₅₀, the greater the toxicity.

Herbicides (common name)	Acute Oral Toxicity	
	LD ₅₀ (mg/kg)	Test animal
Acrolein	46	rat
Endothall (acid)	51	rat
(sodium salt)	190	rat
(amine salt)	206	rat
Dicamba (acid)	2900	rat
Dinoseb (DNBP)	58	rat
Paraquat	120	rat
Picloram (Trodon)	8200	rat
2,4-D (various formulations)	300-1000	rat, guinea pig
Glyphosate (Roundup)	> 5000	rat

■ Toxicity Classification

All pesticides are classified according to their toxicity to man. The following table indicates the relative toxicity of most herbicides to man.

SIGNAL WORD	TOXICITY CATEGORY	LD ₅₀ <i>The amount of pesticide, measured in milligrams per kilograms (mg/Kg) of body weight that will kill one-half of the exposed population.</i>		
		Oral	Common measuring unit	Dermal
DANGER- POISON 	I High toxicity	0 - 50	taste to 1 tsp.	0 - 200
WARNING	II Moderate toxicity	50 - 500	tsp to Tbsp	200 - 2,000
CAUTION	III Low toxicity	500 - 5,000	1 oz to 1 pt	2,000 - 20,000
CAUTION	IV Relatively nontoxic	Over 5,000	more than 1 pt	Over 20,000

Chemical Toxicity

CHEMICAL FAMILY	TOXICITY CLASS			
	I	II	III	IV
acetanilides		✓	✓	
aliphatic carboxylic acid		✓	✓	
amino acids			✓	
benzoic acids			✓	✓
benzonitriles		✓	✓	
bipyridiliums	✓	✓		
carbanilates			✓	
dinitroanilines			✓	
diphenyl ethers			✓	
inorganic compounds			✓	
organic arsenicals		✓	✓	
phenols	✓			
phenoxy compounds (acetic)		✓	✓	
(butyric)			✓	
(propionic)		✓	✓	
(phthalic acid)		✓	✓	
pyridines			✓	
pyridazinones			✓	
thiocarbamates			✓	
s-triazines		✓	✓	
as-triazines			✓	
triazoles		✓	✓	
uracils		✓		✓
ureas			✓	

General Weed Control Review Questions

1. A weed can be defined as:
 - a. a plant growing where it is not wanted.
 - b. a plant out of place.
 - c. a plant that is more harmful than beneficial.
 - d. all the above.
2. Sources of weed infestations include:
 - a. humans, wind, and water.
 - b. wild and domestic animals, planting contamination, farm machinery.
 - c. a and b
 - d. none of the above
3. Perennial weeds may have the following types of root systems:
 - a. rhizomes and stolons
 - b. creeping roots
 - c. bulbs and tubers
 - d. all of the above
4. What growing stage is the best time for controlling annual weeds?
 - a. flowering
 - b. seedling
 - c. vegetative
 - d. mature
5. Perennial weed control is more effective in which growth stages?
 - a. seedling or regrowth
 - b. vegetative or regrowth
 - c. full flower or mature plant
 - d. bud or mature plant
6. Methods of controlling weeds include:
 - a. biological
 - b. chemical
 - c. mechanical
 - d. all the above
7. Pre-emergence treatments are:
 - a. applied to the soil after the crop or weeds have germinated and started to grow.
 - b. made to the soil after the crop is planted, but before emergence of the crop or the weeds.
 - c. applied after the harvest of the crop.
 - d. applied to the stack of hay or straw bales.
8. Rain a few days before spraying can improve penetration of a herbicide into a plant by increasing the wettability of the leaf.
 - a. True
 - b. False
9. Microorganisms in the soil are an important component of herbicide decomposition.
 - a. True
 - b. False
10. Spray drift is dependent only on droplet size.
 - a. True
 - b. False
11. A surfactant is any material that affects the surface properties of spray solutions and includes:
 - a. granules
 - b. stickers
 - c. emulsifiable concentrates
 - d. water dispersible liquids
12. The cuticle is a waxy layer or thin film on the leaf surface which retards the movement of water and gases out of or into the leaf.
 - a. True
 - b. False

RIGHTS-OF-WAY VEGETATION MANAGEMENT

INTRODUCTION

Areas of land used for transportation or utilities and for other services are known as rights-of-way. Included are federal, state, county, and local highways and roads; airports and railroads; telephone and electric transmission lines; transformer stations and substations; drainage culverts and ditches; and public and private irrigation ditch banks.

Rights-of-way are everywhere and their surfaces are extremely variable. They encompass many soil types, climates, vegetation complexes, land-use areas, and types of topography. Rights-of-way are found in densely populated urban areas as well as in rural agricultural areas, forests, and mountains. Because of this diversity, controlling plants in rights-of-way requires a thorough understanding of weed management principles and local hazards.

REASONS FOR RIGHT-OF-WAY VEGETATION MANAGEMENT

The objective of a well planned right-of-way vegetation management program is to safely, efficiently, and effectively maintain rights-of-way. More than 15 million acres of land in the U.S. are presently in use as rights-of-way. They require periodic vegetation management in order to assure their continued efficient and safe use.

The aesthetic, economic and environmental benefits of a good vegetation management program include:

- **Improved highway pavement management.** Properly managed roadside vegetation improves air circulation and increases the amount of sunlight reaching the pavement, thus providing longer dry pavement conditions that significantly extend pavement life.
- **Improved highway safety.** Highway safety is enhanced by managing vegetation to provide adequate sight distance for signs, curves, intersections, traffic signals and driveways. Safety is also enhanced by maintaining a safe recovery area next to the pavement and by keeping the deflection area behind guardrails free of trees and vegetation that could interfere with their function. In addition, vegetation is managed to maintain a free draining roadway surface, reducing the potential for hydroplaning or skidding on ice.
- **Preservation and enhancement of scenic resources.** Vegetation management for the purposes of preserving and enhancing scenic resources includes planting, encouraging natural plant growth and selectively restricting plant growth to screen, preserve, create or enhance views, and to control noxious weeds. Rights-of-way are major contributors to the spreading of noxious weeds across the state and nation.

PLANNING THE CONTROL PROGRAM FOR RIGHTS-OF-WAY

A weed management program must be planned ahead of time to make the best use of personnel and equipment. Usually the best results from soil residuals are achieved before the weeds emerge or when they are small. In general, this means early spring. Where lateral movement of residual herbicides has been observed in previous years, apply lower rates later in the season with a contact herbicide to minimize further movement. Some areas that have been treated for several years may not need treatment at all.

➔ **Equipment.** By adjusting boom and nozzle combinations, the same type of low pressure equipment used for other types of weed control can also be adapted for use along guardrails. Generally, it is sufficient to treat a 3-foot strip under the guardrail. This can be done by a single handheld spray bar with a single nozzle. Or a spray bar with one nozzle that is high enough to clear the rail posts may be placed on fixed mount on the truck. Equipment that automatically adjusts to obstacles is available, making hand held spray bars unnecessary.

A nozzle arrangement that can be useful in this situation is the mounting of two smaller, off-center nozzles approximately 18 inches apart and 15 inches above ground level. One nozzle is placed on a bar in line with the direction of travel and the other nozzle is placed toward the rear. Any shadowing will be eliminated. The pattern width is determined by adjusting the nozzle angle.

➔ **Calibration.** Equipment should be calibrated prior to and at frequent intervals during the spraying operations. See the calibration section of this manual that starts on page 44 for the step-by-step instructions on how to calibrate for right-of-way vegetation management.

➔ **Equipment for Broadleaf Spraying on Roadsides.** Equipment used for broadleaf spraying on roadside vegetation will vary with the mileage for which the highway service unit is responsible. Town departments may not need equipment with the spray mileage capability that a county or state highway department finds necessary. A sprayer holding 100-200 gallons may be more than adequate in one situation, whereas, a 1000-gallon sprayer may be needed for efficient operation in another situation.

The one characteristic that all broadleaf roadside sprayers should have in common is low pressure application. Higher pressures produce greater number of finer droplets that cause increased drift problems.

➔ **Calibration of Truck Mounted Sprayers.** The automatic control systems available for today's equipment will adjust the sprayer output to the selected application rate when the ground speed is within prescribed limits. To be certain that the controls are operating properly, a practice run should be made with clean water and the quantity delivered compared to the area covered. For equipment without automatic controls, it is essential to calibrate before any applications and at any point where a change in nozzles, ground speed, or pressure is required.

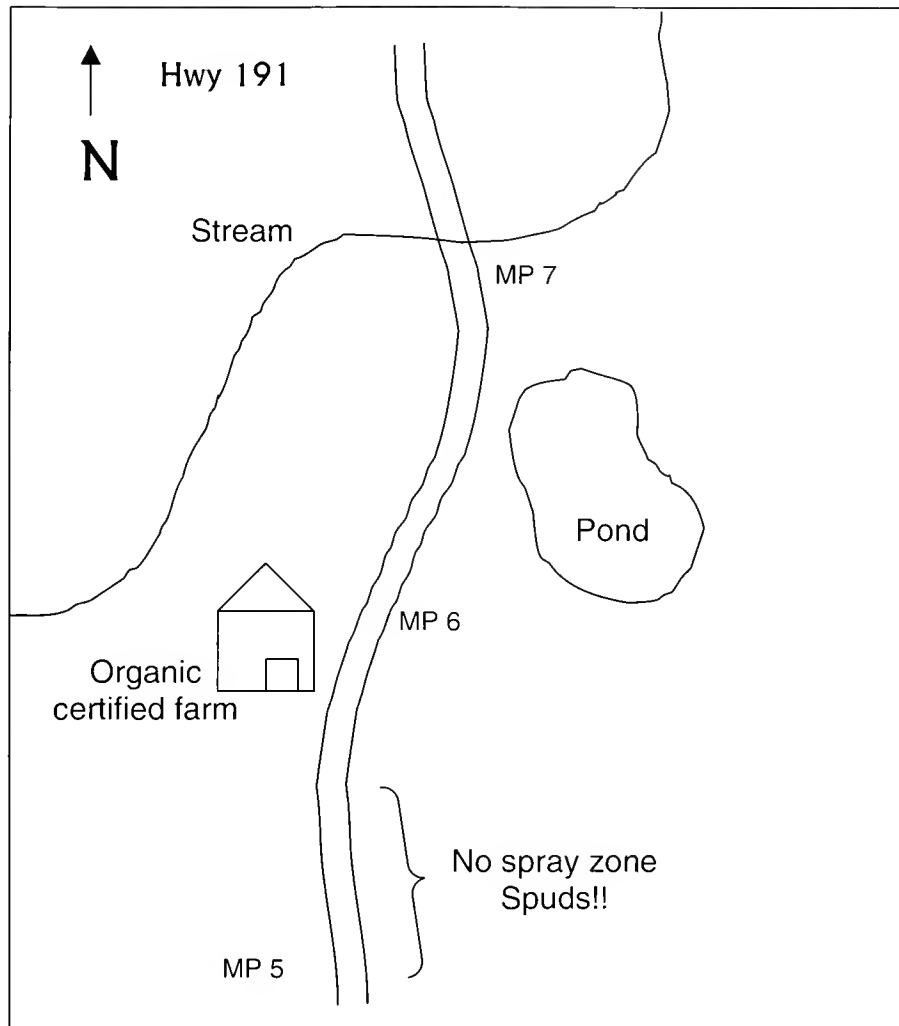
HERBICIDE CONTROL OF RIGHTS-OF-WAY

One way in which management can be provided on rights-of-way is with the use of herbicides. Applications should be made only according to the degree of control needed for safe and efficient use of the right-of-way.

■ General Precautions in Applying Right-of-Way Pesticides

- **Read the label.** The label provides information including hazards, registered uses, dosages, directions for use, etc. Extensive research was required to obtain registration for use and it is a violation of the law to use a pesticide in a manner inconsistent with the labeling. Failure to follow label directions for application methods, allowable concentration, and other label information is illegal. Misapplication could result in damage to desirable vegetation, cause off-target movement of pesticides to neighboring properties, or waterways and adversely affect the pesticide applicator.
- **Avoid physical contact with pesticides.** Pesticides vary in degree of toxicity and individuals vary in sensitivity to such pesticides. In general, you should avoid pesticide contact with skin or clothing and protect your eyes at all times by wearing personal protective equipment. Do not make applications with leaky equipment and wash thoroughly after using pesticides. Do not eat or smoke while handling pesticides. If you get a pesticide on your skin, wash immediately with large amounts of soap and water. See your doctor if symptoms of illness occur during or after use of pesticides; always bring the product label or container with you.
- **Prevent contamination of the environment.** It is illegal to contaminate streams, ponds, or lakes when filling or flushing equipment. Make sure that equipment cannot back-siphon pesticide from the spray tank into a water source.
- **Prevent spray drift.** When possible use low pressures (generally considered less than 40 PSI) and confine foliar application to within 10 feet of the target plant. If your application demands high pressures, anti-drift additives and low drift nozzles may be useful. The single broadjet type nozzle is a useful tool to use to get around milepost delineators and guardrails. Do not make applications when the wind is strong enough to carry spray droplets out of the target area.
- **Avoid certain sensitive areas.** Do not make applications near vegetables, flowers, ornamental shrubs, fruit gardens, home grounds, pastures, animal forage areas, or other areas where off-target application may damage sensitive species. Strip maps are one way to identify sensitive areas on the rights-of-way managed with pesticides. Note sensitive areas, no spray areas, stream crossings, irrigation ditches, and other hazards on the map by milepost numbers. A notebook is a good way to document your notes about the

rights-of-way you are managing. Each page might have 1-3 miles on it with the milepost numbers. Below is an example of a strip map:



➤ **Apply herbicides carefully.** Herbicides are, by definition, plant killers. Each herbicide is unique and designed for a specific job.

➤ **Do not use** a sprayer that has previously been used to apply broadleaf or soil herbicides to apply insecticides or fungicides to ornamentals

HAZARDS WITHIN THE RIGHT-OF-WAY

→ **Injury to Desirable Plants.** Plants within the right-of-way are desirable as ground cover to prevent erosion, habitat for wildlife, and for ornamental value, particularly along highways. Selective herbicides can be chosen that will control the unwanted vegetation, but leave the desired ground cover. Potential drift may warrant switching from foliar application to either basal or cut-stump treatments, which are more selective and safe for desirable ornamentals.

→ **Injury to Roots of Desirable Plants.** You must also consider root absorption of herbicides by desirable ornamentals within the right-of-way. Proper choice of herbicides will prevent root absorption. Glyphosate and simazine are pesticides that can be carefully applied among established woody ornamentals. Imazapyr and tebuthiuron are soil active herbicides that should not be used around woody ornamentals since they will be absorbed by roots in the treated area and may move laterally to damage other ornamentals outside the treated area. The label must be read carefully, in order to determine these potential problems with soil active herbicides.

→ **Brownout.** When foliage is treated with some herbicides, the controlled plants turn brown and are unsightly. In some areas, such as cross country rights-of-way for power lines or along railroads, this is a necessary part of vegetation management. In other areas of high public visibility, such as highways, brownout becomes a serious public relations problem. Most state highway departments specify that along roadsides no vegetation over a given height, usually 2 to 4 feet, may be treated. Instead, they recommend cutting and treating the stumps to prevent regrowth.

→ **Hazards to Pollinators.** You should consider bees, other pollinators and wildlife when making pesticide applications. When using pesticides that are particularly harmful to pollinators, early morning or evening applications when pollinators are not active is recommended in the vicinity of apiaries. Read the label carefully for bee warning statements.

→ **Hazards to Livestock.** Due to the relatively low toxicity of the herbicides used on rights-of-way, it is unlikely that an animal grazing on treated plants would be injured.

Where right-of-way applications take place on land adjacent to pastures or cropland, precautions should be taken to avoid spraying next to pastures preventing overspray or drift from entering the pasture or contaminating crops. Either of these situations could cause a residue to occur on pasture grass or crops that will later be used as livestock feed. These residues could, in turn, cause an illegal residue to occur in the milk and/or meat products from animals that graze on the pasture or eat the contaminated crops. In addition, there is danger of toxicity from poisonous plants that may become more attractive after treatment. For instance, as the foliage of several species of wild cherry wilts, it produces prussic acid, which is very toxic to livestock. The wilting can result from spraying with herbicides or from cutting. Cherry foliage that could wilt from spraying or cutting must be removed to locations where it cannot be consumed by livestock. Another alternative would be to work in these areas when foliage is not present or use cut-stump applications.

ALTERNATIVE RIGHT-OF-WAY CONTROL METHODS

→ **Mechanical Management** is one of the most important and most frequently used control options available in a right-of-way vegetation management scheme. This is primarily because of the extensive mowing carried out along rights-of-way. Mechanical control equipment includes flails and sickle mowers, graders, and tillers.

Mowers cut vegetation without disturbing the root systems of the plants. Tillers and, to a lesser degree, graders disturb root systems. Because the roots of mowed or cut vegetation remain largely intact, the vegetation eventually resprouts and again grows to an undesirable stage. Thus the main drawback of this type of control is the frequency with which control efforts must be undertaken. Mowing is effective when some vegetation is essential for erosion control.

Cuttings can become a fire hazard or block the free flow of water from the surface of the right-of-way. Scalping vegetation can promote invasion of broadleaf weeds into desired grass; it can also cause erosion where little or no vegetation remains. In addition, sparks from the cutting machines can start fires, and the machines can throw rocks into the nearby right-of-way.

Mowers used in mechanical management along rights-of-way come in a variety of sizes and configurations. Large bat-wing mowers are used to mow wide swaths along interstate highways. Other mowing and brush removal equipment is designed to mow along steep grades, remove brush encroaching from the outer limits of the right-of-way, and otherwise provide access to difficult-to-control areas.

Chain saws, weed-eaters, string trimmers, shovels, scythes, and other hand-held tools are commonly used for smaller areas, especially difficult-to-access areas that are beyond the reach of larger mechanical control equipment. They can be used when obstacles prevent the use of larger mechanical control equipment.

Because manual control tools require people to use them, this method is labor-intensive and expensive to undertake. Therefore, manual control is usually restricted to small areas. Beyond the cost in labor, an important consideration in choosing manual control involves the tools themselves, which are often hazardous to the operator even when used properly. In addition, as with mechanical control, cut plants resprout and develop again, so control efforts must be repeated frequently.

→ **Biological Management.** The use of living organisms (insects, diseases, or animals) to control pest organisms is called biological control. Although popular and effective as a means of controlling agriculture and aquatic pests, biological control of weeds in rights-of-way has limitations. Some insect and disease species have been identified for control of certain weeds. However, these beneficials are only available for a limited number of plant species. Their effect often lags behind the development of the target vegetation and biological control agents do not stop the spread of weeds. They are more effective in rangeland setting where high degree of control is not required. Moreover, confining control to the right-of-way is difficult to manage.

➔ **Cultural Management.** Certain cultural management practices can be used to promote development of desired vegetation along a right-of-way. Such practices rely on controlled fire, fertilizers, lime, and mulches. For example, fertilization promotes the development of a dense stand of grass, which impedes weed development along a right-of-way.

Lime can alter the pH of soil, making a particular site unsuitable for certain weed species. Mulches are useful for retarding weed development around landscaped areas.

Fire is used to remove established weeds, thereby eliminating competition for desired grasses and other vegetation that will emerge from the burned site.

Right-of-Way Review Questions

1. Improved highway safety is a benefit of good vegetation management.
 - a. True
 - b. False
2. Making sure equipment cannot back-siphon pesticides from the spray tank into the water source and not contaminating streams, ponds, or lakes when filling or flushing equipment is associated with what general precaution?
 - a. Avoid certain sensitive areas
 - b. Prevent contamination of the environment
 - c. Prevent spray drift areas
 - d. Apply herbicides carefully
3. When foliage is treated with some herbicides, the controlled plants turn brown and are unsightly. This is called _____.
 - a. bad herbicide.
 - b. over applied.
 - c. burnt application.
 - d. brownout.
4. You should consider root absorption of herbicides by desirable ornamentals within the right-of-way.
 - a. True
 - b. False
5. Due to the high toxicity of the herbicides used on rights-of-way it is likely that animals grazing on treated plants would be injured.
 - a. True
 - b. False
6. A disadvantage to using a mower to cut the rights-of-way are:
 - a. not very labor intensive.
 - b. mowers only cut broadleaf weeds.
 - c. cuttings can become a fire hazard or block the free flow of water.
 - d. mowers provide access to difficult-to-control areas.
7. Mowing is effective when some vegetation is essential for erosion control.
 - a. True
 - b. False
8. Biological control agents are often used to control target vegetation and prevent the spread of weeds.
 - a. True
 - b. False
9. The use of living organisms to control pests is called _____.
 - a. mechanical control
 - b. herbicide control
 - c. insecticide control
 - d. biological control
10. Biological control agents are more effective in rangeland settings where high degree of control is not required.
 - a. True
 - b. False
11. Cultural management relies on practices such as controlled fire, fertilizers, lime, and mulches to promote desired vegetation.
 - a. True
 - b. False

APPLYING HERBICIDES SAFELY AND ACCURATELY

INTRODUCTION

Successful weed management relies on integrating many weed control strategies, which should include herbicides and application methods that ensure effective weed control with minimal adverse environmental effects. Consider potential drift, leaching, and residual activity. Know what susceptible vegetation is nearby and select an appropriate application method. Use application equipment that can uniformly deliver the herbicide to the target area and keep the equipment in good working order to ensure accurate application.

Calibrate your equipment to deliver the proper volume to the target area. Then, calculate the amount of herbicide and carrier (if needed) necessary for the job from the application rate specified on the label. Improper calibration or calculations lead to either poor weed control or injury to desirable vegetation because the applicator puts on too little or too much chemical. Not only is misapplication environmentally and economically wise, it is also illegal.

Your goal is to make any herbicide application at the best time for weed control and protection of desirable vegetation, such as prior to emergence. Consider growth stages and stresses on both weeds and desirable plants.

TYPES OF APPLICATION

The application method you choose depends primarily on the product and the equipment you have available. Other factors include the characteristics of the weed or site and the relative cost and effectiveness of alternative methods. You often have a choice between methods. The principal objective with any herbicide application is to safely and effectively bring the chemical into contact with the targeted weed(s). Common herbicide application methods may be referred to according to timing of the application, placement of application, or volume/material applied.

Common timing for herbicide applications include:

- ♦ Pre-plant. Where the application and incorporation of the herbicide is made prior to planting. It uses tillage equipment or overhead moisture to mix the herbicide with the soil. The herbicide is then available to kill germinating weed seeds.
- ♦ Pre-emergence application puts herbicide directly in or on the soil before weeds or desirable vegetation emerge. It may also be a foliar application to weeds, prior to emergence of desirable vegetation.
- ♦ Post-emergence application puts herbicide on plant foliage. At the time of foliar applications, plants should not be under moisture, heat, or other stress. Avoid drift to nearby sensitive vegetation.

Common placement methods include:

- ♦ Broadcast treatment or blanket application is a uniform treatment of an entire area. It can be made pre-plant, preemergence, or postemergence.

- ♦ Spot treatments are applied to a localized or restricted area, usually to control a small weed infestation requiring special attention. Non-selective or residual herbicides sometimes are used on perennial weed infestations to prevent their spread.
- ♦ Band treatment usually means treating a strip. This reduces chemical cost because the treatment band covers less area than a broadcast application. It may be made pre-plant, preemergence, or postemergence. It is often used with mechanical controls.
- ♦ Directed sprays keep herbicides off desirable vegetation. Such sprays are usually directed at or just above the ground line, treating only the lower part of the plant stem or trunk, or treating vegetation on the base of a tree.
- ♦ Cut-stump treatments are made to the freshly cut stump surfaces so that herbicide moves down into the roots to control resprouting. Cut surfaces begin to dry within minutes of cutting.

The application methods mentioned above can range from high volume to ultralow volume. Notice that many of the herbicide treatments also utilize mechanical, cultural, and other control methods. The most effective weed management programs use more than a single control method.

APPLICATION EQUIPMENT

Selecting proper application equipment depends on the type of application. Equipment choice depends on site working conditions, pesticide formulation, type of area to be treated, and possible problems. While large power-driven equipment may be desirable for some jobs, other jobs are done best by small portable or hand-held equipment. Most application equipment falls into two groups: one group applies dry pesticide formulations and the other applies pesticides in a liquid carrier (water, oil, liquid fertilizer).

Equipment for Dry Applications

Granular applicators apply coarse, dry, uniformly-sized particles to the soil. Several types of dry spreaders exist: pneumatic whirling disks (seeders, fertilizer spreaders), multiple gravity-feed outlets (lawn spreaders, fertilizer spreaders), multiple air-driven feed outlets, and ram-air (aircraft). Some applications use shaker cans and hand distribution of pellet formulations.

Although they vary greatly in design, granular applicators normally consist of a hopper to hold the herbicide, a mechanical-type agitator at the base of the hopper to provide a uniform and continuous feed, and some type of metering device, usually a slit-type gate to regulate the granule flow.

Equipment for Liquid Applications

Most herbicides are applied as liquids with sprayers. Different types and sizes of sprayers vary from hand-operated units to machines with 100-foot booms. Most apply dilute herbicide mixtures, while others apply concentrates. Most use low pressure (<40 psi) and low volume. Some apply spray through single outlets or nozzles, while others use multiple nozzles linked by sections of pipe or tubing to form a boom or spray head. The principal types used for weed control are discussed below. Variations or combinations of these types also exist.

Sprayer Components

Tanks. Sprayer tanks must allow easy use, cleanup, and maintenance. They must be made of material that resists corrosion from various formulations. Suitable tank materials include polyethylene (do not use with ammonium phosphate solutions and complete-analysis fertilizers; ultraviolet light causes polyethylene to break down), fiberglass (may be affected by some solvents), and stainless steel. Some pesticides corrode aluminum, galvanized, and steel tanks.

Tanks should:

- ♦ have large openings for easy filling and cleaning,
- ♦ allow straining during filling
- ♦ allow for mechanical or hydraulic agitation,
- ♦ have a large drain,
- ♦ have a cutoff valve for storing liquid pesticide temporarily while other parts are being serviced, and
- ♦ outlets sized to the pump capacity.

Pumps must be large enough to supply the volume needed for the nozzles, the hydraulic agitator (if necessary), and to maintain the desired pressure. The pump parts should be resistant to corrosion and abrasion if abrasive materials, such as wettable powders, are used. Select gaskets, plunger caps, and impellers resistant to swelling and chemical breakdown caused by some liquid pesticides. Consult your dealer for available options.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps can be damaged if run dry or if they have a restricted inlet or outlet. Pumps depend on the spray liquid for lubrication and removal of friction heat.

Agitators mix the components of the spray mixture uniformly and, for some formulations, keep the material in suspension. If agitation is inadequate, the actual application rate of the pesticide may vary as the tank empties. The two common types of agitators are hydraulic and mechanical.

Strainers. Filtering the spray mixture protects the working parts of the spraying system and prevents clogged nozzle tips. As the mixture moves through the system, strainer openings should be progressively smaller. Strainer mesh is described by the number of openings per linear inch: a high number indicates a fine screen. Place strainers on the filler opening, on the suction or supply line to the pump, between the pressure relief valve and the boom, and on the nozzle body. Clean the strainers after each use. Replace damaged or deteriorated strainers.

Hoses. Use weather-resistant, synthetic rubber or plastic hoses that have a burst strength greater than peak operating pressures, and that resist oil and solvents present in pesticides and adjuvants. Keep hoses from kinking or being rubbed. Rinse them often, inside and out, to prolong hose life. Store them out of the sun. Replace hoses at first sign of surface deterioration. Make sure hose fittings are free of leaks. Frequently inspect all hoses and fittings.

Pressure gauges monitor your spraying system. They must be accurate and have the range needed for your work. For example, a 0-100 psi gauge with 2-lb gradations is adequate for most sprayers. Check frequently for accuracy. If the gauge does not zero properly, replace it.

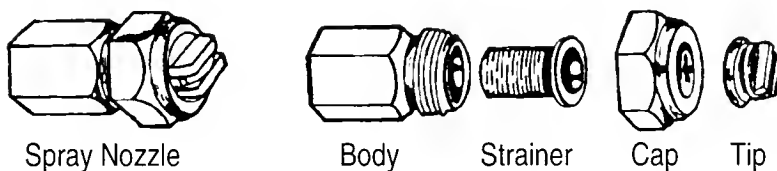
Pressure regulators control the pressure, and indirectly, the quantity of spray material delivered by the nozzles. They protect pump seals, hoses, and other sprayer parts from damage due to excessive pressure.

Control valves. Make sure quick-acting cutoff valves are located between the pressure regulator and the nozzles to provide positive on-off action. Have cutoff valves that stop all flow or flow in any section of the spraying system within easy reach of the sprayer operator.

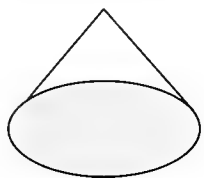
Nozzles. Nozzle tips break the liquid into droplets. They also distribute the spray in a predetermined pattern and help control the application rate. Nozzle performance depends on:

- ♦ nozzle design or type,
- ♦ size of the spray tip opening (orifice),
- ♦ operating pressure,
- ♦ discharge angle,
- ♦ spacing between nozzles, and
- ♦ distance between the nozzle and target.

Nozzles have four major parts: nozzle body, strainer (screen), cap, and tip or orifice plate. Successful spraying depends on correct nozzle selection, assembly, and maintenance.



Nozzle patterns come in three basic types: solid stream, fan, and cone. Some special purpose nozzle tips or devices produce special patterns. These include solid cone, flood, and others that produce wide-angle fan or off-centered patterns. Check with the nozzle manufacturer's literature for the best nozzle for your job. Certain nozzle types may be better suited for contact herbicides because of different droplet sizes and resulting coverage.



Solid Cone Nozzle



Flat Fan Nozzle



Flood Nozzle

Ceramic nozzles are most resistant to abrasion and corrosion and are the most expensive. Stainless steel tips resist corrosion and abrasion, especially if they are hardened stainless steel; they are moderately priced. Brass tips are less expensive than stainless steel and resist corrosion

(except from fertilizers) but not abrasion. Nylon tips wear out like brass, will not corrode, but may swell when exposed to some organic solvents. Aluminum tips wear quickly, are inexpensive, and resist some corrosive materials.

Operating and Maintaining Sprayers

Properly operate and maintain spray equipment for safe and effective herbicide application. This will significantly reduce repair costs and prolong sprayer life. This will also ensure effective, consistent weed control while minimizing chemical costs.

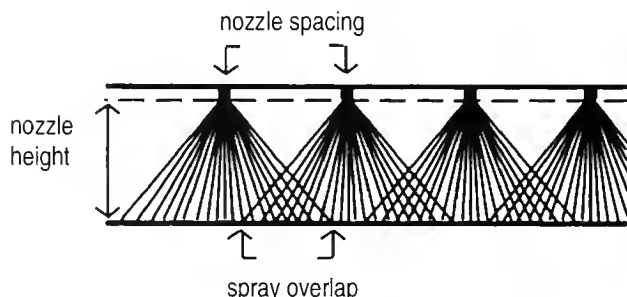
Before Spraying - Thoroughly rinse the sprayer with clean water. Check gauges and tank. Make sure nozzles are the appropriate type for the job. If using nozzles with check valves, make sure they are working properly. Check valves prevent dripping when flow to the nozzle drops below a certain pressure. Check the spraying system for leaks and output pattern.

Precalibration Check

- ✓ Clean system
- ✓ Strainers in appropriate locations
- ✓ Agitator works properly
- ✓ Nozzles- appropriate type and size
- ✓ Nozzle output within 5% of rating
- ✓ Proper nozzle alignment
- ✓ Correct boom height and nozzle spacing
- ✓ Accurate pressure gauge
- ✓ Speed of travel check
- ✓ Accurate tank volume markings

If using a boom type sprayer, make sure each nozzle output does not differ by 5% more or less from the average. If it does, check screens, nozzles, hoses, etc. before changing that nozzle. If more than one nozzle varies by 5% replace all the nozzles, because this strongly indicates excessive wear of the entire system. Also check the nozzle height, measuring the distance between the nozzle tip and target and adjust the boom accordingly. Boom height is very important in broadcast application because it affects uniformity of the spray pattern.

Check the nozzle manufacturer's recommendations for nozzle spacing, pattern overlap, alignment, and boom height above the target.



Make sure the tank is level during filling so that the gauge shows the amount in the tank correctly. Know the true volume levels of your equipment. Factory sight gauges and volume markers can be incorrect, resulting in miscalibration or misapplication.

During Spraying - Frequently check the pressure gauge and speedometer or tachometer while spraying, making sure that the sprayer is operating at the same pressure and speed used when it was calibrated. Speeds should be reasonable so that sprayer booms are not bouncing or swaying excessively. Periodically check hoses and fittings for leaks. Check nozzles for unusual patterns.

If emergency repairs or adjustments are necessary, always use adequate protective clothing, particularly rubber gloves. Use an old toothbrush to unclog nozzles. Never use metal wire to unclog a nozzle because it may distort the nozzle opening and change the spray pattern and output.

After Spraying - Always flush the spray system, inside and out, with water after each use to prevent chemical buildup. Make the initial rinse of the inside of the tank at the application site. Apply the rinsate onto the site to reduce the generation and concentration of wastes at the clean-up area. You will need extra water on site (saddle tank or truck).

Clean the inside and outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. All equipment and equipment parts exposed to a pesticide will normally have some residue, including sprayer pumps, tank, hoses, and boom. Wear personal protective equipment to prevent skin contact with these residues.

Many herbicide labels describe specific instructions for cleaning sprayers because certain tank cleaners work better on certain herbicides. If labels do not list specific cleaning directions, use the following guidelines:

- Flush the sprayer tank, lines, and booms thoroughly with clean water and apply the pesticide-contaminated rinsate to labeled sites or use rinsate in subsequent spray batches.
- Fill the sprayer to capacity with water, adding one cup of trisodium phosphate or household ammonia for each 10 gallons of water. If neither is available, use a strong detergent or soap. Only ammonia will remove hormone-type (2,4-D) or sulfonyleurea (Oust) herbicides.
- Wash the tank and pump parts thoroughly by running the sprayer for about 5 minutes with the spray boom off.
- If possible, let the cleaning solution stand in the sprayer overnight. (Household ammonia will corrode aluminum sprayer parts.)
- Discharge the liquid from the tank, spraying some through the nozzles.
- Drain the sprayer completely and remove nozzles, screens, and strainers.
- Scrub all accessible parts with a stiff bristle brush.
- Rinse the sprayer (inside and outside) thoroughly with clean water and reassemble.

Storage of Sprayers - Clean the sprayer thoroughly before storing for the season. Then add 1 to 5 gallons of lightweight emulsifiable oil (depending on the size of the tank) to an equal volume of clean water. Flush the entire system with the oil-water mixture. As the mixture is pumped from the sprayer, the oil will leave a protective coating on the inside of the tank, pump, and plumbing.

Remove, clean, and place all nozzles and screens in a dry place to prevent corrosion. Cover the nozzle openings in the sprayer boom with tape to keep dirt out. When storing for the winter, drain water from pumps, or it may freeze and crack the pump (if not stored in a heated building). As an added precaution to protect pumps, you may pour one tablespoon of radiator rust-inhibitor antifreeze into the pump inlet. Turn the pump several revolutions to coat the internal surfaces.

CALIBRATION

The challenge for any pesticide applicator is twofold:

1. How to apply a small amount of pesticide to a large area, usually expressed in acres.
2. How much pesticide is added with water (or other diluent) in the tank to spray a given area.

Usually a pesticide label will call for a certain amount of pesticide to be applied **per acre**. In order to physically apply a small amount of pesticide over a large area, the pesticide concentrate must be diluted with a diluent. In most cases, the diluent is water. The point being that it is easier to apply 20 gallons of water mixed with a small amount of pesticide over an acre than it is to apply the pesticide alone over that same entire acre.

For this reason, it is important to know how much liquid a sprayer can apply on a per acre basis. This is known as the application rate, sprayer output or delivery rate and is generally expressed in Gallons Per Acre or GPA. Your GPA is based on three factors:

1. The speed at which you apply the pesticide.
2. The output of your nozzles.
3. The pressure of your sprayer.

When you calibrate a sprayer, you are determining your sprayer's output in GPA.

To spray pesticides in a cost effective manner, there must be consistency between calibration and actual application. If you calibrate your sprayer at a certain speed or pressure, make sure you use the same speed and pressure when you apply the pesticide. In addition, the accurate application of pesticides at the proper dosage is dependent upon 3 major factors.

1. Determination of the proper product **rate** from the label - 1 pint/acre, 1 quart/acre, etc.
2. Sprayer application rate (output) in Gallons Per Acre (**GPA**).
3. How many **acres** can your sprayer covers with a given volume of liquid.

The purpose of calibration is to ensure that application equipment uniformly applies the labeled rate of product over a given area. Too little herbicide results in poor weed control and a waste of money. Over application may result in damage to the desirable vegetation, pollution, environmental damage and human health problems.

Application equipment suppliers often provide specifications on equipment set-up in order to apply a given GPA. However, such sources of information usually only estimate delivery rates and cannot account for equipment wear and variations in gauges, speedometers, and plumbing. You must calibrate equipment to obtain more reliable determinations of equipment delivery rates.

To properly calibrate, depending on type of equipment, you may need a bucket marked in gallons, a stopwatch, tools, a container marked in ounces for nozzle output, a tape measure, and flags or stakes for marking distances. Unless your equipment is new, it probably has some pesticide residue in and on the various equipment components; therefore, wear a pair of rubber gloves. In addition, a pocket calculator helps reduce mathematical errors.

Sprayer Calibration

The following calibration technique, the calibration-strip method, is only one of many used for boom sprayers. The Basic Manual uses a different calibration method, but for the exam, use the calibration method in this training manual. In the field you can choose which method is best for you.

The calibration strip method is based upon the idea of applying small amount of liquid to a portion of an acre and then converting it to a per-acre basis. For example, you could fill a spray tank with water, spray an entire acre and then determine how many gallons were used – Gallons Per Acre or GPA. To save time, why not only spray $\frac{1}{4}$ of an acre, determine how many gallons were used and then multiply by 4. With the calibration strip method, the area of the “strip” is the width of your spray pattern (swath) in feet times a distance of your choosing. Most applicators use 100 or 200 feet.

Calibrating A Broadjet or Boomless Sprayer

Broadjet or boomless sprayers enable a wide swath to be sprayed without using a series of nozzles across a boom. Swath widths vary with different brands of nozzles and can range from 10 feet on up. Calibration of these sprayers is also easy as there are generally only one or two nozzles.

Step 1: Set out a calibration test strip. First, determine the effective swath width or the width of the spray pattern as it appears on the ground. Then mark a course length, usually 100 or 200 feet.

Step 2: Find the area of the calibration strip [200 feet x swath width (feet)], and convert it to acres (calibration strip area \div 43,560 ft²).

Step 3: Use the Nozzle Collection or Refill technique to measure the amount of liquid applied per strip (in gallons). Remember you are only using water to calibrate your sprayer.

Nozzle Collection Technique

Fill the sprayer with water. For the same time it took you to drive the calibration strip (200 ft.) at field speed, collect water from the nozzle using the same pressure as you would in the field. Measure the amount collected and convert to gallons.

Refill Technique

Fill the sprayer to a known mark. Spray the 200-foot course at the same speed and pressure used when actually spraying. Refill the tank to the known mark using a gallon container to measure the amount of water sprayed.

Step 4: $\frac{\text{Gallons applied per strip}}{\text{Test strip Acreage}} = \text{Gallons Per Acre applied.}$

Example: A boomless sprayer has a swath width of 30 feet. Using 200 feet as the test strip length, the area of the calibration strip is 6000 ft² (200 ft x 30 ft).

The acreage of the strip is 6000 ft² ÷ 43,560 ft² or 0.1377 acres. You drove the calibration strip in 27 seconds, stopped and collected from under the nozzle for 27 seconds or you can use the refill method. You collected 3 gallons. Your sprayer is calibrated at 21.78 gallons per acre or 22 GPA (3 gallons per strip ÷ 0.1377 acres per strip). Remember! When you start spraying, maintain the same speed and sprayer pressure as when you calibrated.

Calibration of Boom Sprayers With Multiple Nozzles

The calibration of multi-nozzle boom sprayers is complicated by the fact that you want a fairly uniform output across the boom. If any one nozzle is providing more or less liquid, then the effectiveness of the pesticide application may be affected. Therefore, with boom sprayers it is important to:

- Check the output from each nozzle individually.
- Establish an average as a benchmark.
- Using the average, establish an error range in order to judge the nozzles and make a decision to replace or clean the nozzles.

Checking Nozzle Output

The flow from some nozzles may be more or less than others. This will create an uneven swath pattern. To overcome this you should collect from under each nozzle for a standard amount of time (usually 30 seconds to one minute) and take the average flow of all the nozzles. If the flow of any nozzle varies by more than 5%, on either side of the average, then those nozzles should be cleaned or replaced.

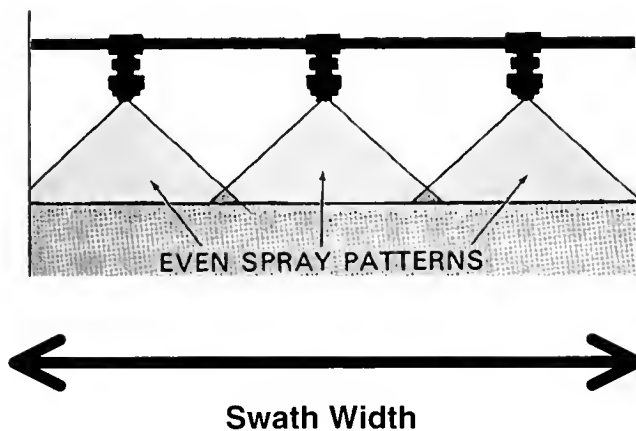
First, find the 10% error, by simply taking the average and moving the decimal place one space to the left. Now divide that number in half to find a 5% error. For example, suppose we have an average nozzle output of 60 ounces per minute. Moving the decimal one place to the left is 6.0 ounces (10% of 60). Half of 6.0 is 3.0 ounces (5% of 60). So the “low” side of 60 is 57 while the high side of 60 is 63 for a 5% error. Any nozzle delivering between 57 and 63 ounces per minute falls within the acceptable 5% error range on either side of the average. Any nozzle delivering outside of this range needs to either be cleaned or replaced.

Example: Suppose you had six nozzles on a boom and you collected from under each nozzle for one minute.

Nozzle # ⇒	1	2	3	4	5	6
Ounces	45	47	35	48	54	46

- The average output of all the nozzles is $275 \div 6 = 45.8$ or 46
- Five percent either side of 46 is 43.7 and 48.3
- Nozzle numbers 3 and 5 are outside of this range and need to be cleaned or replaced.

Once you have checked all your nozzles for uniform output, the calibration process is the same as calibrating a broadjet:



1. Find the effective swath width created by all the nozzles.
2. Mark out a 200-foot course to verify your speed. Time yourself in seconds.
3. Multiply your swath x 200 ft to find the area of your calibration strip.
4. Determine the acreage of your calibration test strip (calibration strip $\text{ft}^2 \div 43,560 \text{ ft}^2$).
5. Collect liquid from each nozzle for the amount of time it took to drive the strip and pour the liquid collected from all the nozzles into one container or use the refill technique.

$$\frac{\text{Gallons applied per strip}}{\text{Test strip Acreage}} = \text{Gallons Per Acre applied.}$$

Example: Suppose you have a 6-nozzle boom and have checked each nozzle and they all fall within a 5% error range on either side of the average nozzle output.

- Suppose the effective swath width produced by all the nozzles is 10 feet.
- The area of our calibration strip is 2000 ft^2 (200 ft. x 10 ft).
- The acreage of our calibration strip is $2000 \text{ ft}^2 \div 43,560 \text{ ft}^2$ or 0.0459 acres
- We drive the 200-foot course and time ourselves. It takes 27 seconds.
- We stop and collect from under each nozzle for 27 seconds or use the refill method.
- We collect 1 gallon and 1 quart (1.25 gallons) from all the nozzles.
- The sprayer is calibrated to 27.23 or 27 GPA (1.25 gallons per strip \div 0.0459 acres).

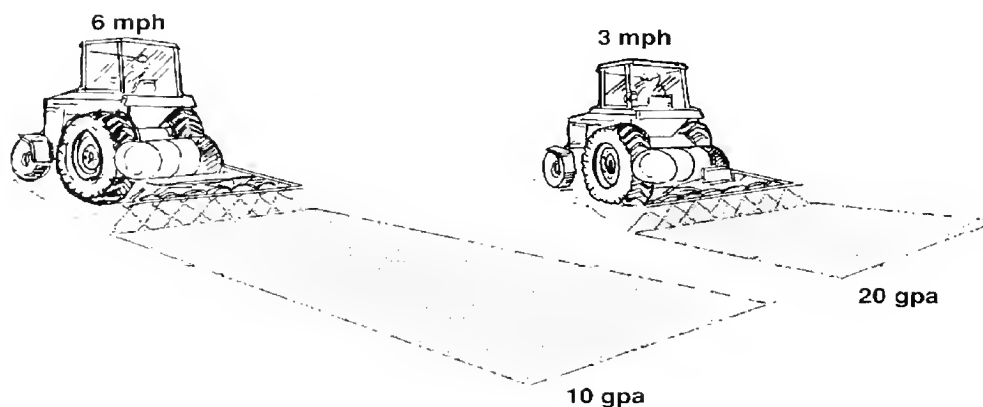
Adjusting Output

You may have calibrated your sprayer only to find that its GPA is either too high or too low. Labels can be very specific in requiring certain volumes to be applied in order to improve pesticide performance, uptake, and to prevent drift. On the other hand, the lower the GPA, the more acres you can treat with a given volume.

In order to affect output, there are three things to consider:

1. Speed
2. Nozzles
3. Pressure

To make big changes in output (GPA), you can adjust your speed. As you slow down, you apply more. As you speed up, you apply less. If you are applying 20 GPA at 3 MPH and you double your speed to 6 MPH, you will apply half as much (10 GPA).



To make moderate changes in output, it is best to change nozzles unless you can fine-tune your speed with the use of speed sensors. For small changes in output, you can adjust sprayer pressure. But this is for minor changes only.

In order to double your output using pressure, you will need to increase your pressure fourfold. For example if a sprayer's output is 1 gallon per minute at 10 pounds per square inch (PSI), you will need to increase the pressure to 40 PSI to achieve 2 gallons per minute. Increasing pressure can lead to drift problems, increased incidences of equipment failure, and improper coverage or placement of the pesticides. It is best to use pressure to fine-tune a sprayer's output and use speed or different nozzles for major adjustments.

Handheld and Backpack Sprayer Calibration

Measure out an area 18 ½ by 18 ½ feet. This equals 340 square feet or approximately 1/128 of an acre. Adjust the sprayer to the desired pressure and spray pattern and measure the time it takes to spray the test area. Repeat this several times and take the average time. Using a container graduated in ounces, spray into the container for the same amount of time it took to spray the measured area. The amount collected in ounces equals the application in gallons per acre.

Example:

- Measure area. $18 \frac{1}{2} \text{ ft.} \times 18 \frac{1}{2} \text{ ft.} = 340 \text{ ft}^2 = 1/128 \text{ acre.}$
- Time to spray area = 146 seconds
- Spray into container for 146 seconds
- Amount collected = 73 ounces

Therefore: 73 ounces in the container equals 73 gallons per acre application rate.

Mixing and Calculations

The amount of herbicide formulation to be added to the spray tank is dependent upon:

1. Volume of pesticide mixture to be used.
2. Sprayer output in gallons per acre (GPA).
3. The recommended product rate of pesticide.

You first need to know how much area you can treat with a given volume!

$$\frac{\text{Volume to be used}}{\text{Output (GPA)}} = \text{Acres treated}$$

Example: Your sprayer is calibrated to 25 GPA and you are going to use a full 500 gallon tank.

$$\frac{500 \text{ gallons}}{25 \text{ GPA}} = 20 \text{ acres}$$

Example: Your sprayer is calibrated to 25 GPA and you are going to use 250 gallons of a 500 gallon tank.

$$\frac{250 \text{ gallons}}{25 \text{ GPA}} = 10 \text{ acres}$$

Example: Your 2 gallon backpack sprayer is calibrated at 35 GPA and you plan on using a full 2 gallon tank.

$$\frac{2 \text{ gallons}}{35 \text{ GPA}} = 0.057 \text{ acres or } 2483 \text{ ft}^2 \text{ (} 43,560 \text{ ft}^2 \text{ per acre} \times 0.057 \text{)}$$

Once you determine how many acres you can spray with a given volume, you can then determine how much pesticide you need to add to that given amount of volume in the spray tank.

Acres treated x product rate = How much you need to add to a given volume in the tank

For instance, suppose a label calls for a rate of 1 pint/acre and you can spray 20 acres with 500 gallons of water (at 25 GPA).

1 pint/acre x 20 acres = 20 pints of pesticide and water to make a 500 gallon solution.

Since there are 8 pints in a gallon you will need to add 2 ½ gallons of pesticide to the tank. Fill the tank half full with the desired volume of water, add the pesticide, surfactants, and then top off with water to the desired volume.

Suppose you have that backpack that can treat 0.057 acres with 2 gallons of water (35 GPA). The label recommends a 1 pint per acre rate to control a particular pest. One pint equals 16 ounces so:

$$0.057 \text{ acres} \times 16 \text{ oz.} = 0.912 \text{ or } 1 \text{ ounce of pesticide per 2 gallons of water.}$$

Other Mixing Consideration

- How much of the actual pesticide formulation do you add to the tank when the rate is given according to pounds of active ingredient (a.i.) per acre, such as with university recommendations or with label restrictions?

$$\frac{\text{Labeled Rate Per Acre}}{\text{Amount of a.i. per gallon}} = \text{Amount to apply in terms of gallons}$$

Example: A university bulletin recommends that you apply 3 lb per acre of the active ingredient (a.i.) of a particular pesticide. The pesticide label indicates that there are 8 lbs. of a.i. per gallon of formulation.

$$3 \text{ lbs. per acre} \div 8 \text{ lbs. a.i per gallon} = 0.375 \text{ gallons of the actual formulation per acre.}$$

Another Example: You have calibrated a 300-gallon sprayer. It can spray 7.5 acres per tank at 40 GPA. A recommendation indicates you should apply ½ pound a.i. of a pesticide per acre. The label that is on the pesticide states it contains 2 pounds of a.i. per gallon. How much of the pesticide formulation will you add to the tank to spray 7.5 acres?

$$\frac{0.50 \text{ lb a.i./acre}}{2 \text{ lb a.i./gallon}} = 0.25 \text{ gallon (1 quart) per acre}$$

$$7.5 \text{ acres per tank} \times 1 \text{ quart per acre} = 7.5 \text{ quarts}$$

- How much dry pesticide do you apply per acre when the rate is given as a percentage of active ingredient (a.i.)?

$$\text{Recommended rate} \div \% \text{ a.i. per lbs of formulation} = \text{lbs. of formulation per acre}$$

Example: A recommended rate of 0.2 lbs. a.i. per acre of a 25% wettable powder (WP) is recommended. (one pound of formulation contains 0.25 lbs. a.i.).

$$0.2 \text{ lbs. per acre} \div 0.25 \text{ a.i.} = 0.80 \text{ lb formulation per acre}$$

$$\text{To convert to ounces: } 0.80 \text{ lbs.} \times 16 \text{ ounces per dry lbs.} = 12.8 \text{ ounces per acre.}$$

Applying Herbicides Safely and Accurately Review Questions

1. The component on a sprayer that keeps the spray mixture uniformly and the material in suspension is called _____.
 - a. strainer.
 - b. agitator.
 - c. pump.
 - d. pressure gauge.
2. The four major parts of a spray nozzle are:
 - a. body, pump, strainer, tip
 - b. body, strainer, spray nozzle, tip
 - c. strainer, agitator, cap, tip
 - d. body, strainer, cap, tip
3. Which type of nozzle is the most resistant to abrasion and corrosion?
 - a. ceramic
 - b. brass
 - c. nylon
 - d. aluminum
4. Frequently checking the pressure gauge and speedometer while spraying ensures proper operation of the sprayer.
 - a. T
 - b. F
5. Before storing for the season, sprayers should just be cleaned with water.
 - a. T
 - b. F
6. All equipment and equipment parts exposed to a pesticide will normally have some residue.
 - a. T
 - b. F
7. The output of all 6 nozzles is 245 ounces. What is the 5% error range for these nozzles?
 - a. 38.9 – 43.1 ounces
 - b. 36.9 – 45.1 ounces
 - c. 30.9 – 40.1 ounces
 - d. 36.0 – 46.0 ounces
8. The acreage of a calibration strip is 3000 ft² and it takes 27 seconds to drive the course. 1.25 gallons were collected from all the nozzles. Calibrate the gallons per acre (GPA).
 - a. 24.1 GPA
 - b. 22.1 GPA
 - c. 20.1 GPA
 - d. 18.1 GPA
9. Use the above answer to calculate how many acres a 250 gallon spray tank can treat.
 - a. 12.4 acres
 - b. 13.8 acres
 - c. 11.3 acres
 - d. 10.4 acres
10. A pesticide label calls for a rate of 1 pint/acre and you can spray 16 acres with 250 gallons of water. How many gallons of herbicide do you need to add to the spray tank?
 - a. 2 gallons
 - b. 2.5 gallons
 - c. 3 gallons
 - d. 3.5 gallons

APPENDIX A

NOXIOUS WEEDS IN MONTANA

Control of noxious weeds should be of concern to every landowner and land manager in Montana. An integrated weed management approach of good farming and ranch management practices; cultivation, mechanical, and cultural methods; biological control when available; and herbicides will continue to aid the control of noxious weeds. The pages that follow give a brief description of the most serious noxious weeds threatening Montana agriculture. For specific control information on all weeds refer to current Cooperative Extension publications or contact your local weed district. For color plates and a more complete description of these weeds refer to publications found in Appendix C of this manual. Noxious weeds are defined by rule in the County Noxious Control Act. The three categories in weed classification are defined as follows:

MONTANA COUNTY NOXIOUS WEED CLASSIFICATION

CATEGORY 1

Category 1 noxious weeds are weeds that are currently established and generally widespread in many counties of the state. Management criteria includes awareness and education, containment and suppression of existing infestations, and prevention of new infestations. These weeds are capable of rapid spread and render land unfit or greatly limit beneficial uses.

CATEGORY 2

Category 2 noxious weeds were recently introduced into the state or are rapidly spreading from their current infestation sites. These weeds are capable of rapid spread and invasion of lands, rendering lands unfit for beneficial uses. Management criteria includes awareness and education, monitoring and containment of known infestations, and eradication where possible.

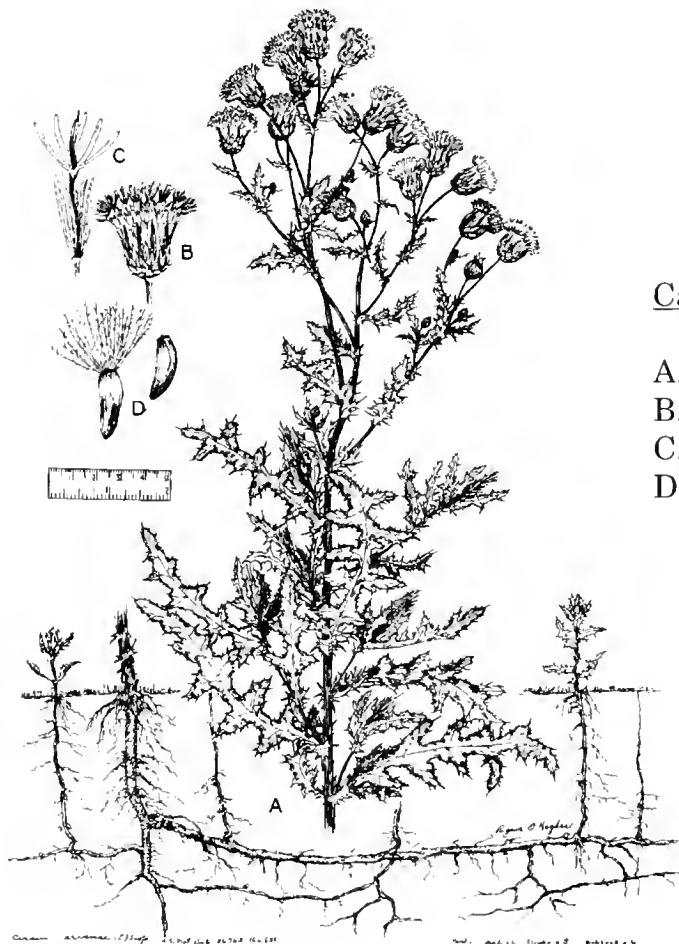
CATEGORY 3

Category 3 noxious weeds have not been detected in the state or may be found only in small, scattered, localized infestations. Management criteria includes awareness and education, early detection, and immediate action to eradicate infestations. These weeds are known pests in nearby states and are capable of rapid spread and render land unfit for beneficial uses.

Canada Thistle (*Cirsium arvense*)

Canada thistle is a perennial plant reproducing by creeping rhizomes (horizontal roots) and by seed. The extensive roots are fleshy and send up frequent new shoots. The stems are erect, hollow, smooth or slightly hairy, up to 4 feet high and branched at the top. The plants are leafy but no wings or spines occur on the stem. The wavy leaves are oblong to lance shaped and vary from irregular and deeply cut, to spiny toothed on the margins, to almost smooth with few or no spines. The color is usually bright green but the upper surface varies from dark to light and the leaves are sometimes very light green and slightly hairy on the underside. The flowers are numerous, small, compact, and vary from light lavender or white to rose-purple. There are many flower heads clustered together on the ends of branches. Canada thistle flower heads often appear much smaller than most other thistles. The bract on the heads are not spiny. The plant is dioecious, with male and female flowers produced on separate plants. Seeds are oblong, flattened, curved, smooth, dark brown, and approximately 1/8 inch long.

Canada thistle is an introduced species from Eurasia and grows throughout the northern half of the United States and north into Canada from British Columbia to Quebec. It grows in all crops, pastures, meadows, and waste places in rich, heavy soils. Canada thistle is a serious threat to grain crops in Montana. Wheat yields have been reduced by 15 to 60% in infested areas.



Canada Thistle

- A. Plant Habit
- B. Head
- C. Flower
- D. Achenes

Helpful identification tip:
Bracts under the flowers are spineless.

Field Bindweed (*Convolvulus arvensis*)

Field bindweed is a viney, weak-stemmed, persistent perennial weed. It reproduces from an extensive root stock, rhizomes, and abundantly produced seeds. The plant forms a mat on the soil surface with prostrate stems 2 to 7 feet long that can climb short distances. The roots may extend 20 to 30 feet into the soil. The leaves are dull green and vary in size and shape, depending on soil fertility and moisture. Characteristically, they are ovate oblong with acute spreading basal lobes. The leaves have short leaf stalks that alternate on the stem. The plants flower from May to August and the flowers are white to light pink in color, funnel-shaped and borne on slender 1 to 2 inch stalks in the leaf axis. A pair of narrow, pointed leaflike structures (bracts) are found on the flower stalks 1/2 to 1 inch below the flower. The seed pod is round, pointed, light brown, and contains four seeds. The seeds are dark-brown with a roughened surface, three-angled, and 1/8 to 1/5 inch long.

This plant was introduced from Eurasia and is now found throughout the United States except in the extreme Southeast and a few areas in the Southwest. It grows well under most cultivated conditions as well as in all uncultivated and waste places. It is extremely difficult to eradicate due to its low growth and widespread, deeply penetrating root system. It is a serious problem in cropland in Montana.



Field Bindweed

- A. Plant Habit
- B. Rootstock
- C. Leaf Variation
- D. Flower
- E. Capsule
- F. Seeds

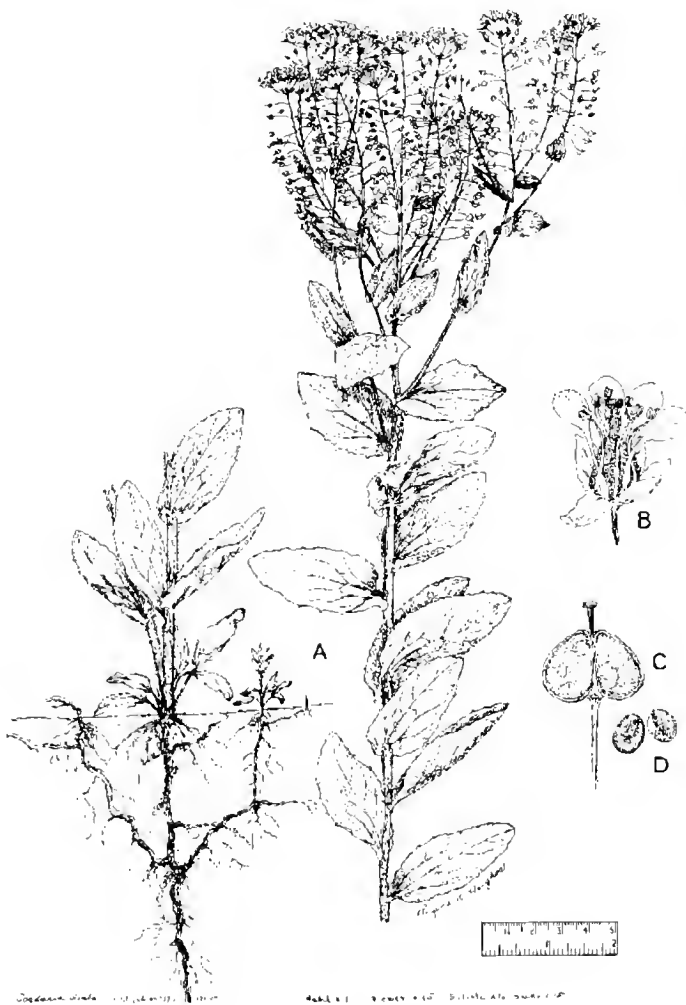
Helpful identification tip:
Leaves of field bindweed are shaped like arrowheads.

Whitetop (*Cardaria draba*)

Whitetop (hoary cress) is a perennial reproducing by seed and rhizomes. It has numerous erect stems 1 to 2 feet high that are branched at the top. An extensive root system spreads both horizontally and vertically with frequent shoots arising from the root stock. The plant seems to be gray green due to many fine hairs on the leaves. The leaves are simple, alternate, oblong, toothed and the upper leaves have a broad clasping base. The flowers are white, four parted, about 1/8 inch wide and borne in flat-topped clusters. Seed pods are slightly flattened, two-valved, heart-shaped with a prominent persisting style. The seeds are oval, slightly flattened, granular with reddish-brown seed coats.

Whitetop is naturalized from Europe and found throughout the United States except in the Southcentral area. It is found in pastures, cultivated fields, hay fields, meadows, waste places, and roadsides. It is most common in western and central Montana.

Helpful identification tip:
Many white flowers with four petals develop into bladder-like seed capsules in mid-summer.



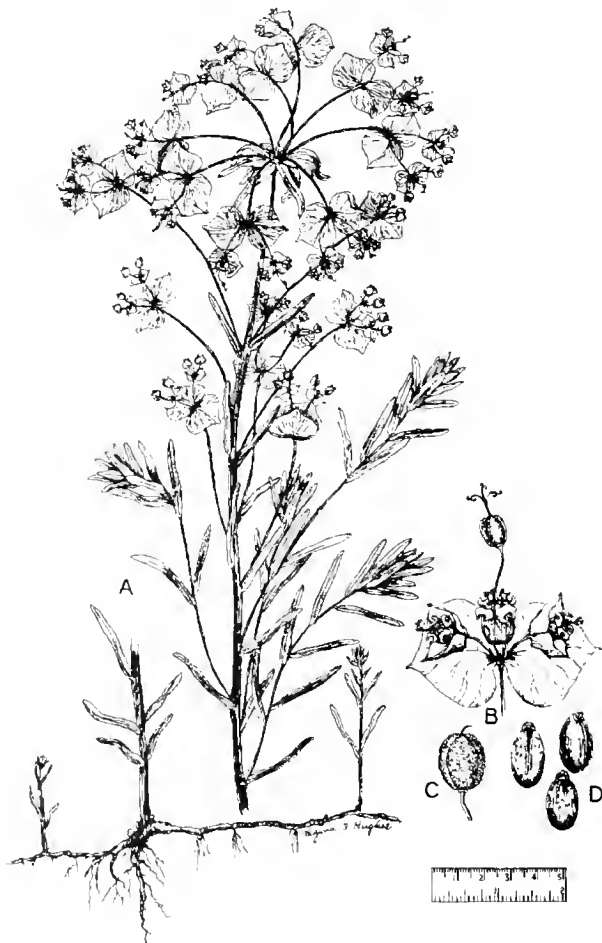
Whitetop

- A. Plant Habit
- B. Flower
- C. Silicle
- D. Seeds

Leafy Spurge (*Euphorbia esula*)

Leafy spurge is a perennial, reproducing by seed as well as an extensive underground rhizome system. The heavy running roots are woody, persistent and widespread and give rise to dense colonies of the plant. Pink buds on creeping rhizomes give rise to roots and shoots every few inches. The stems are erect, smooth, and branched at the top. The entire plant is a dull green color with milky juice and grows about 2 feet tall. The leaves are alternate and irregularly spaced along the stem. There is a whorl of lance-shaped leaves at the base of the umbel. The flowers are inconspicuous and are formed above pairs of rounded floral bracts on repeated forking stems arranged in a flat-topped umbel. When in full bloom the entire umbel, including the bract, turns a bright greenish yellow. The seed pods are on a short stalk from the cup-like base. Seeds are oblong, grayish to purple, contained in a 3-celled capsule, each cell containing a single seed.

Leafy spurge is an introduced plant from Europe. It is found in most of the northern United States and Canada. It grows readily in waste areas, pastures, roadsides, cultivated fields and sandy banks. It can be toxic to cattle, but sheep do well eating it. Leafy spurge is one of the most persistent noxious weeds in Montana. It is found throughout the state and has a wide habitat suitability, prolific reproduction capabilities, strong competitive ability and is difficult to control.



Leafy Spurge

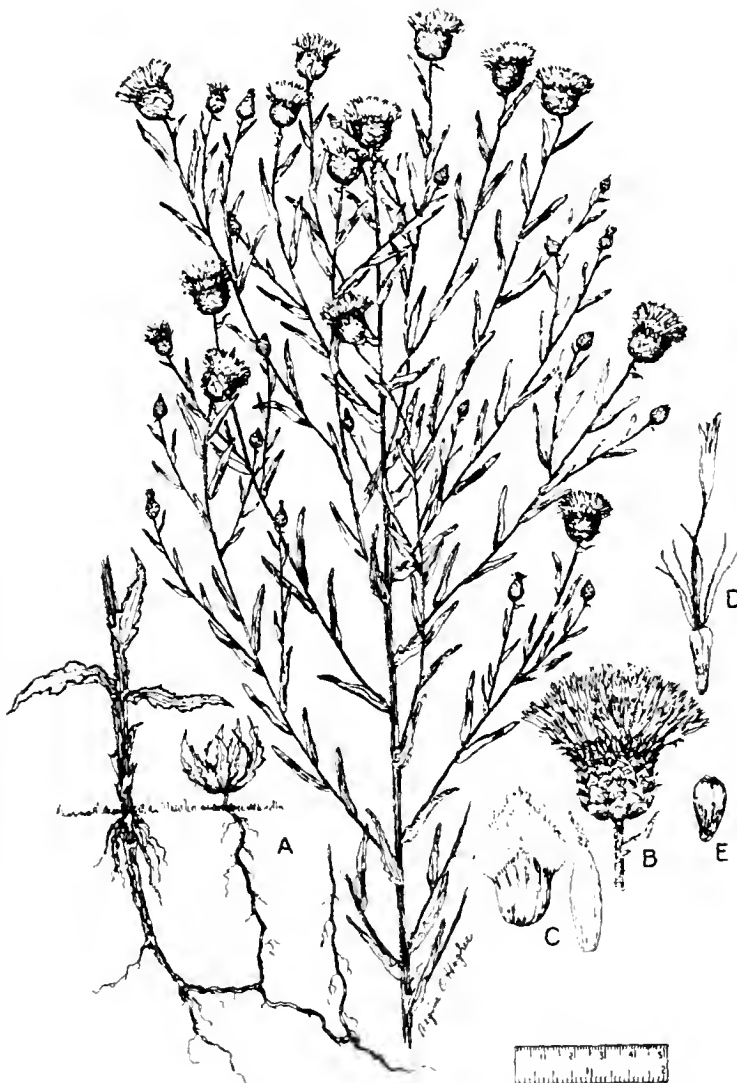
- A. Plant Habit
- B. Flower Cluster
- C. Capsule
- D. Seeds

Helpful identification tip: Heart-shaped yellow bracts surround the 3-celled seed capsule, each cell containing a single seed.

Russian Knapweed (*Centaurea repens*)

Russian knapweed is a bushy, branched perennial plant reproducing by seed and underground rhizomes. The roots are characteristically black in color and have a scaly appearance. The stems are erect, 2 to 3 feet tall, branched at the base, ridged and have a dense gray hair-like covering. The basal leaves are hairy and the upper leaves are small and linear with smooth edges. The intermediate leaves have slightly toothed margins. The flowers are 1/2 inch wide, rose to purple composite heads and solitary on the ends of leafy branches. The seeds are grayish to yellow, smooth, flattened, oval, and about 1/8 of an inch long. The flowers generally bloom from June to August.

Russian knapweed was introduced from southern Russia and Asia. It grows in pastures, grain fields, cultivated fields, meadows, waste places, roadsides, and irrigation ditches. It is found throughout Montana. Once established it will completely crowd out other vegetation.



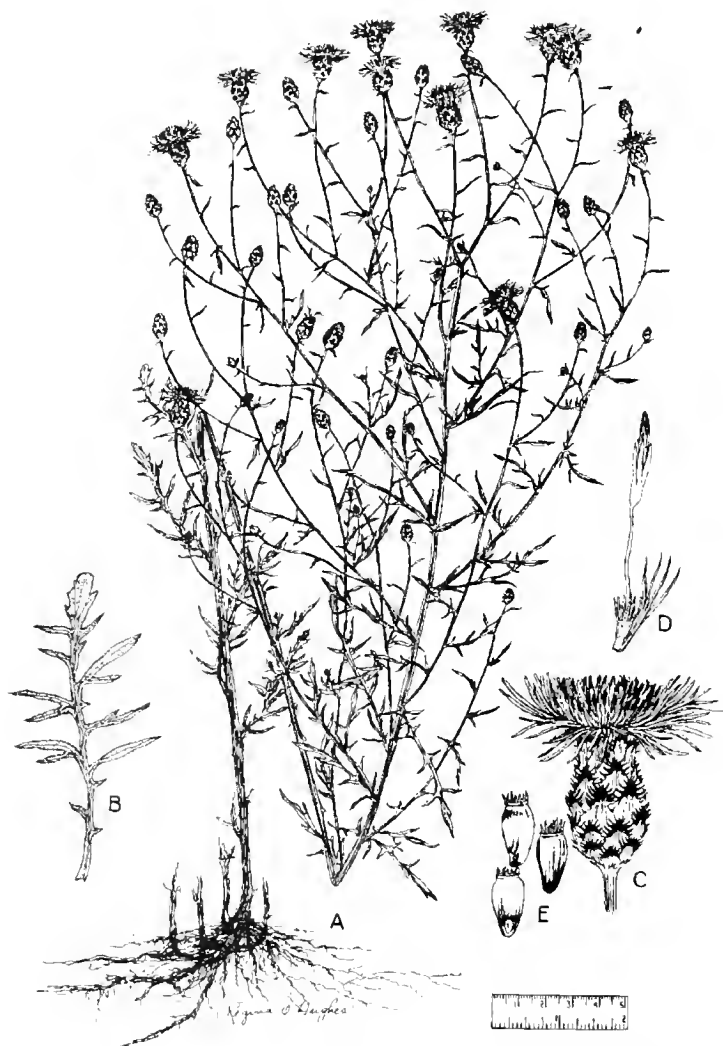
Russian Knapweed

- A. Plant Habit
- B. Head
- C. Bracts
- D. Flower
- E. Achene

Helpful identification tip: Bracts under the flower are rounded with pointed papery tips.

Spotted knapweed was introduced and naturalized from Europe. It is often found in dry gravelly or sandy pastures, old fields, and along roadsides. It readily invades pastures and can take over nearby range and pasture. Spotted knapweed is found in every county in Montana but the heaviest infestations are in the western part of the state.

- A. Plant Habit
- B. Enlarged Leaf
- C. Flower Head
- D. Disk Flower
- E. Achenes



Helpful identification tip: Bracts under the flowers have dark spots tipped with fringe.

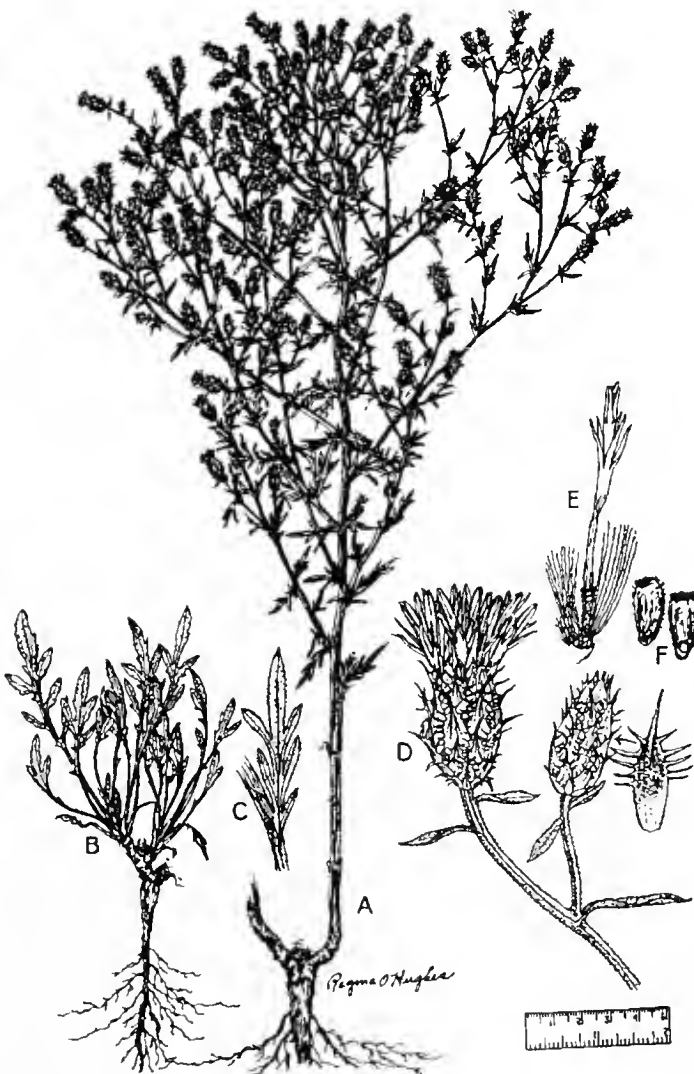
Diffuse Knapweed (*Centaurea diffusa*)

Diffuse knapweed is a biennial or short-lived perennial forb that grows to a height of 1 to 3 feet. It has a taproot and only one or very few stalks. The tip of each branch has a single flower head. The flowers are most commonly white with the upper portion of the bract narrowing to a distinct spine. Often the outer most flowers are sterile. The bracts are yellowish green with a light brown margin. Seeds are achenes, dark brown, 1 inch long, with faint pale brown or ivory lines.

Diffuse knapweed grows well in dry sites and is found on waste grounds, fields, and along roadways in many areas of western Montana. The most serious infestation is located near East Helena.

Diffuse Knapweed

- A. Plant Habit
- B. Young Rosette
- C. Leaf
- D. Flower Head
- E. Flower
- F. Achenes



Helpful identification tip: Bracts under the flower have yellow spines with teeth appearing as a comb along the spine margins.

Dalmatian Toadflax (*Linaria dalmatica*)

Dalmatian toadflax is a perennial, reproducing by seed and creeping rootstock. The plants are erect, about 2 feet tall, pale green and have showy, yellow flowers. The spurred flowers are tinged with orange and are about 1 inch long. The leaves are broad, heart-shaped, and clasp the stem.

Dalmatian toadflax is a native of the Mediterranean region. It is found scattered throughout the northern and western United States. It is an escaped ornamental found along roadsides and near dwellings, spreading to valleys and sagebrush flats. Large infestations are found in several Montana counties.



Helpful identification tip: Early spring growth of this prolific perennial has waxy leaves with a blue-green color.

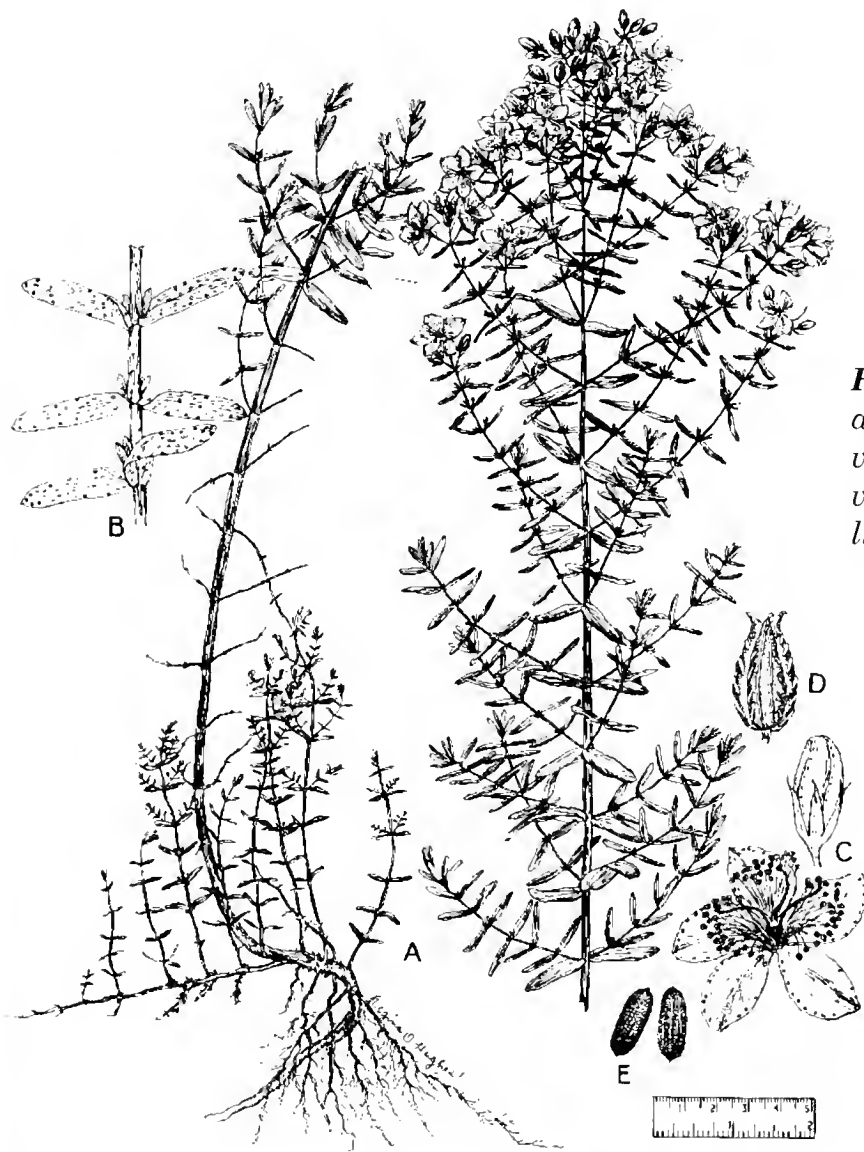
Dalmatian Toadflax

- A. Plant Habit
- B. Flower
- C. Capsule
- D. Seeds

St. Johnswort (*Hypericum perforatum*)

St. Johnswort (goatweed) is a perennial forb reproducing by seed and from rootstock. Stems are smooth, branched, about 3 feet tall and woody at the base. The opposite leaves are elliptic to oblong and have small, glandular dots. The orange-yellow flowers are about 3/4 inch in diameter and five-petaled. The three-parted seed pods are round, pointed, and contain many seeds.

St. Johnswort is common in dry pastures, rangelands, and neglected fields and along roadsides in western Montana. It is not readily grazed by livestock and causes photosensitization in light skinned animals. It should be regarded as a poisonous plant. It is difficult to control.



Helpful identification tip: Leaves are oval in shape with prominent veins. Tiny transparent dots are visible when leaves are held up to a light source.

St. Johnswort

- A. Plant Habit
- B. Enlarged Leaves
- C. Flower and Bud
- D. Capsule
- E. Seeds

Hypericum perforatum L. as ref. and described above

Model 1: Leaves x 2 Flower + bud x 4 Capsule x 4 Seeds x 20 (Magnified 100x)

Sulfur Cinquefoil (*Potentilla recta*)

Sulfur cinquefoil is a long-lived perennial forb that begins growth early in the spring. It reproduces by seed and can produce 1,650 seeds per year. Although it does not reproduce vegetatively, as old roots die in the center, new shoots grow from the edges and can form a ring-shaped clump of individual plants. Plants 20 to 30 years old have been reported in Michigan.

Sulfur cinquefoil produces one to several erect stems which vary from 12 to 28 inches in height. The compound leaves have five to seven leaflets arranged in a palmate pattern. Numerous leaves are attached along the length of the stem, but few of them grow from the base of the plant. The leaflets decrease in size, and the length of the leafstalks get shorter near the top of the stem. Uppermost leaves are attached directly to the stem. Stems and leafstalks are hairy.

This noxious weed is adapted to a wide range of environmental conditions. It grows in open grasslands, shrubby areas and open forest and logged areas, often in association with spotted knapweed. Disturbed sites such as roadsides, waste areas, logged areas and abandoned fields are easily invaded by sulfur cinquefoil. It is widely distributed in Montana.



Sulfur Cinquefoil

- A. Plant Habit
- B. Base of leaf showing stipules
- C. Flower and calyx
- D. Achenes

Helpful identification tips:

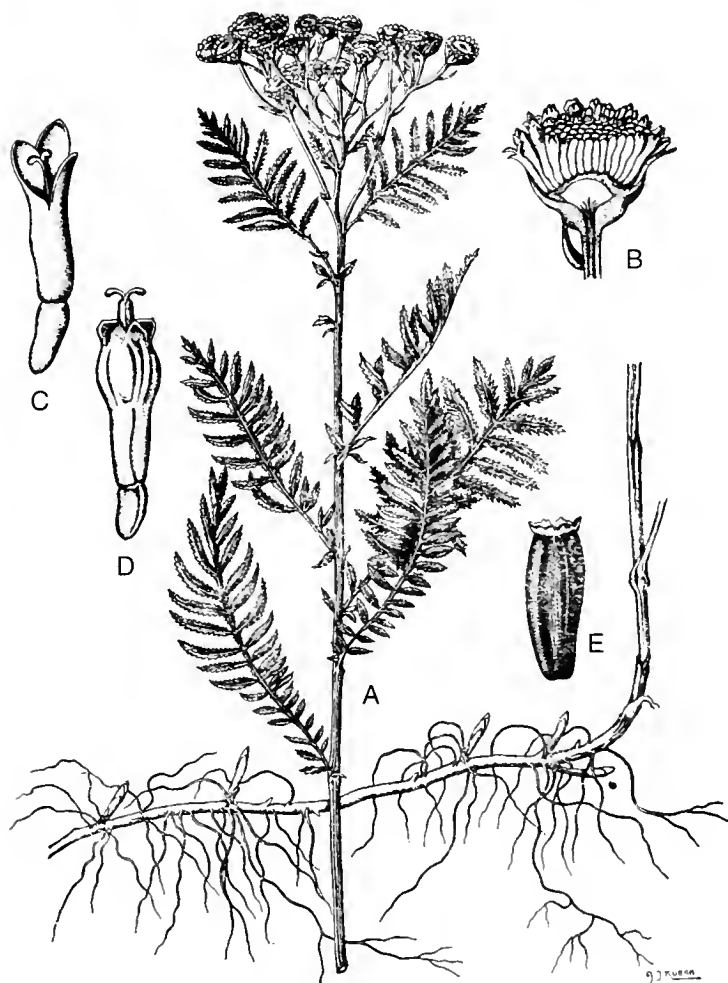
Long, right angled hairs on stem; many stem leaves, few basal leaves; net-like seed coat; and pale yellow flowers.

Common Tansy (*Tanacetum vulgare*)

Common tansy, also known as golden buttons and garden tansy, is an aromatic perennial. Stems are 1 1/2 to 6 feet tall. It reproduces from seeds and rootstalks. Leaves are alternate, deeply divided into numerous narrow, toothed segments. Yellow flower heads, 1/4 to 1/2 inch across, are numerous in flat-topped dense clusters. Seeds are yellowish-brown with short 5-toothed crowns.

Common tansy is a native of Europe and became established in the U.S. when introduced as an ornamental and for medicinal purposes. It is generally found along roadsides, waste areas, streambanks, and in pastures throughout most of the U.S. and Canada.

The plants contain alkaloids that are toxic to both humans and livestock if consumed in large quantities. Cases of livestock poisoning are rare, though, because tansy is unpalatable to grazing animals. In addition, hand pulling of common tansy has been reported to cause illness, suggesting toxins may be absorbed through the skin and gloves should be worn when pulling this noxious weed.



Common Tansy

- A. Plant Habit
- B. Flower Head
- C. Stigma
- D. Disk Flower
- E. Achenes

Helpful identification tips:

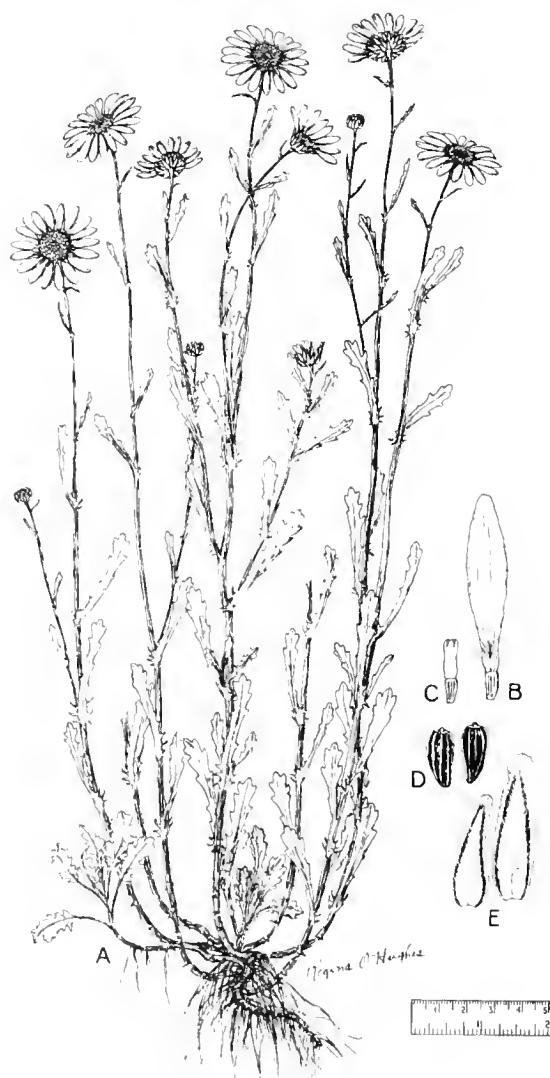
Leaves are divided into individual leaflets, which are serrated on the margins. Stems are often purplish-red in color.

Oxeye Daisy (Chrysanthemum leucanthemum)

Oxeye daisy is an erect rhizomatous perennial, 10 to 24 inches tall, glabrous to sparsely hairy. Leaves progressively reduce in size upward on stem. Basal and lower stem leaves are oblanceolate to narrowly obovate, 2 to 5 inches long including the petiole, margin crenate to lobed or parted. Upper leaves become sessile and merely toothed. Flowering heads are solitary at the ends of branches, about 1 1/2 inches long. Fruits have about 10 ribs.

Scentless chamomile and Shasta daisy look very similar to oxeye daisy. However, chamomile is an annual plant with smaller flowers and much more finely dissected leaves. Shasta daisy usually grows 6 to 12 inches taller than oxeye daisy and has larger flower heads. Flowering of oxeye daisy occurs from June through August. The plant is a prolific seed producer; a single, healthy, robust plant produces up to 26,000 seeds in addition to the spreading rootstalks.

Oxeye daisy was introduced to the U.S. from Europe as a contaminant in seed and as an ornamental. It quickly escaped cultivation and has since become a noxious weed. It can be found in meadows, roadsides, and waste places.



Oxeye-Daisy

- A. Plant Habit
- B. Ray Flower
- C. Disk Flower
- D. Achenes
- E. Involucral Bract

Helpful identification tips:
 Leaves of this creeping perennial have lobed margins with basal leaves growing up to 5 inches long.

Houndstongue (*Cynoglossum officinale*)

Houndstongue is a biennial growing 1 to 4 feet tall and reproducing by seed. Leaves are alternate, 1 to 12 inches long, 1 to 3 inches wide, rough, hairy, and lacking teeth or lobes. Flowers are reddish-purple and terminal. The fruit is composed of 4 prickly nutlets each about 1/3 inch long.

Houndstongue was introduced from Europe. It forms a rosette the first year and sends up a flowering stalk the second year. The leaves are rough and resemble a hound's tongue. It may be found in pastures, along roadsides and in disturbed habitats. The nutlets break apart at maturity and cling to clothing or animals. Houndstongue is toxic, containing pyrrolizidine alkaloids, causing liver cells to stop reproducing. Animals may survive for six months or longer after they have consumed a lethal amount. Sheep are more resistant to houndstongue poisoning than are cattle or horses. Therefore, ranges and pastures should be maintained to encourage production of grasses and high quality forage.



Houndstongue

- A. Plant Habit
- B. Nutlets
- C. Rosette (1st year growth)

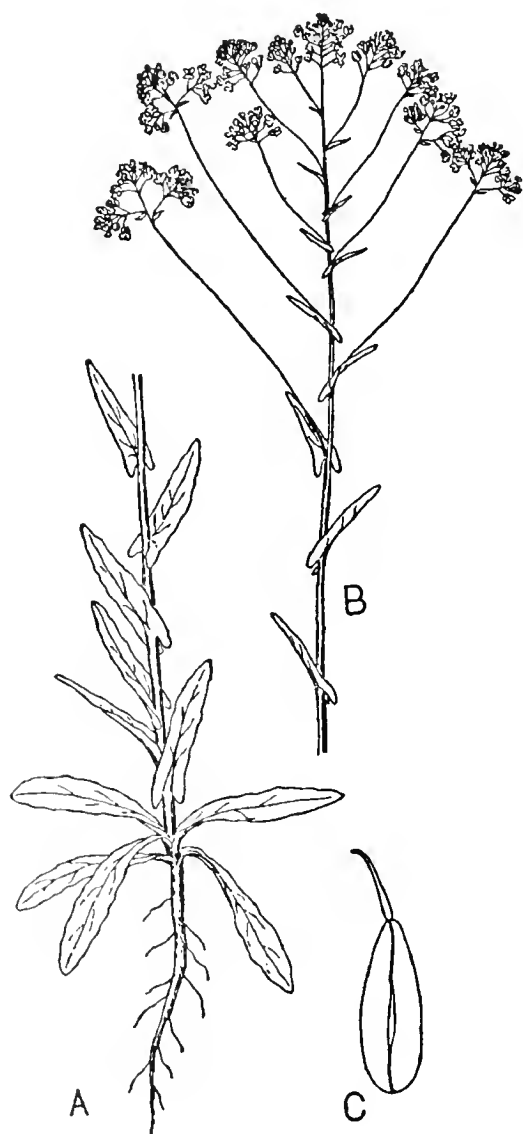
Helpful identification tips:

In the second year, houndstongue plants flower and produce an abundant supply of seeds that spread by attaching to clothing or animals.

Dyers Woad (*Isatis tinctoria*)

Dyers woad can be a perennial, biennial or annual forb reproducing by seeds and from roots. The plants may grow from 1 to 3 feet tall and have a smooth, bluish-green color. The lower leaves clasp the stem with ear-like projections. The yellow flowers are very small and form a flat-topped inflorescence. The seed pods are about 1/2 inch long, winged like a maple seed and turn black when mature.

Dyers woad is native to Europe. It's name comes from Germany where dye was extracted from the purplish black seed pods. It is a serious weed problem in both Utah and Idaho and can be found in several locations in Montana. It spreads readily by seed from roadsides to rangeland and crops. Detection and eradication is imperative for Montana.



Helpful identification tip:

Purplish-brown seed pods containing a single seed appear near mid-summer, giving this weed a totally different appearance.

Dyers Woad

- A. Plant Habit
- B. Flower Head
- C. Fruit

Purple Loosestrife (Lythrum salicaria)

Purple loosestrife is an exotic perennial plant that infests wetlands. The seed germinates in the spring and summer, although seedlings do not typically flower in their first season. In autumn, the stems die back and the plant remains dormant through the winter. The following spring, new stems form from root buds. Flowering starts in late June and continues into September. Rose-purple flowers with spike-like panicles are borne on upright 3- to 5-inch stalks. Single plants continue increasing in size with each subsequent year of growth. New shoots form at the base of the plant, resulting in dense stands. These dense clumps of semi-woody stalks resist decay, and overtime, debris becomes trapped between roots and stems, resulting in the elevation of the ground level. This eliminates water-dependent species such as cattail, rushes and sedges. The tall stalks create shade that is detrimental to the growth of pond weeds that serve as a source of wildlife food. In addition, the vigorous growth and extensive seed dispersal give purple loosestrife a significant competitive advantage over most native species.

Purple loosestrife, a native of Europe and Asia, was introduced into North America in the early 1800s. It has been found in flood plains, along drainage ditches and on marsh edges in several places in Montana. The most severe infestations are often found in areas where the natural vegetation has been disturbed or eliminated. This plant is a serious threat to wetlands.



Helpful identification tip:

Lance-shaped leaves with smooth margins are arranged in whorls or may be opposite on the stem.

Tansy Ragwort (Senecio jacobaea)

Tansy ragwort is a biennial or short-lived perennial plant. Most seeds germinate in the fall, form a rosette the following year and flower and set seed the next year. If the plant is cut, pulled or broken the second year this damage results in regrowth and blossoming during the third year. Tansy ragwort has daisy-like golden flowers with a long blossoming period. The rosettes have irregular, lobed leaves with a visible blade region near the tip. The stems are 1 to 6 feet high. The leaves, 5 to 9 inches long, are attached directly to the main stalk. Leaf color may vary from light to dark green. The plant spreads principally by seeds, and individual plants may have as many as 150,000 seeds.

Tansy ragwort is a native of Europe. It grows well in pastures and disturbed areas on a wide range of soil types. It can survive under most soil moisture conditions and does well through the Northwest area. Hot dry summer and very low (-20 degrees) winter temperatures do not adversely affect this plant. The plant is toxic to both cattle and horses, and to some extent sheep. Alkaloids found in all parts of the plant cause irreversible liver damage. This plant is currently one of the most serious weed problems in Oregon and is also found in northern California, western Washington and British Columbia. It is found in limited areas of western Montana and detection and eradication programs are important to keep it from spreading.

Helpful identification tip: Rosettes have leaves that are deeply lobed and the compound leaflets are also lobed.



Tansy Ragwort

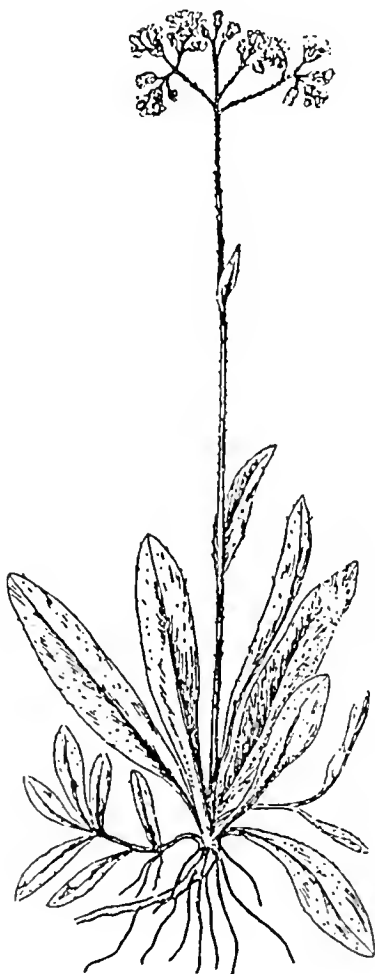
- A. Plant Habit
- B. Flower Head
- C. Ray Flower
- D. Disk Flower
- E. Achenes (ray flower)
- F. Achenes (disk flower)

Meadow Hawkweed Complex (*Hieracium pratense*, *H. floribundum*, *H. piloselloides*)

Meadow hawkweeds are perennial weeds with shallow, fibrous roots. Leaves are hairy, up to 6 inches long, spatula shaped, and almost exclusively basal. Stolons are extensive, creating a dense mat of hawkweed plants that practically eliminates other vegetation. Stems are bristly and usually leafless, although occasionally a small leaf appears near the midpoint. Stems can reach a height of 3 feet and bear up to thirty, 1/2 inch, flower heads near the top. Flowers are yellow and appear in late May or June. Stems and leaves exude milky juice when broken. Seeds are black, tiny, and plumed.

Meadow hawkweed was introduced into the United States from Europe. Spread is aided by contaminated grass seed. It is an extremely aggressive weed that invades and dominates hay fields, meadows, pastures, riparian areas, rights-of-way and similar sites. It is found widely in northwestern Montana.

Native hawkweeds differ from introduced hawkweeds because they lack stolons and have numerous upper stem leaves and a branched, open, flower arrangement.



Helpful identification tip:

Narrow, spatula-shaped leaves are 4 to 6 inches long, dark green above, and light green beneath.

Orange Hawkweed (*Hieracium aurantiacum*)

Orange hawkweed is a perennial weed with shallow, fibrous roots. Leaves are hairy, spatula shaped, up to 5 inches long, and almost exclusively basal. Extensive stolons create a dense mat of hawkweed plants that practically eliminates other vegetation. Stems are usually leafless, although occasionally a small leaf appears near the midpoint. Stems may reach a height of 1 foot and bear up to thirty, 1/2 inch, flower heads near the top. Flowers are red to orange and appear in late May or June. Stems and leaves exude a milky latex when cut or broken. Seeds are tiny and plumed.

Orange hawkweed is native to Europe. It is common in the eastern United States, where it has become a troublesome weed. It invades meadows, pastures, roadsides, tree plantations, riparian areas, and urban sites. Orange hawkweed is widely distributed in northwestern Montana.

Native hawkweeds differ from introduced hawkweeds because they lack stolons and have numerous upper stem leaves and a branched, open, flower arrangement.



Helpful identification tip: Shorter than meadow hawkweed, red to orange flowers, and spreads less rapidly than meadow hawkweed.

Tall Buttercup (*Ranunculus acris*)

Tall buttercup is also known as meadow buttercup, tall crow-foot, blister plant, gold cup, and butter-rose. This hairy perennial, often reaches 3 feet in height, with stems much branched above. Lower leaves 3- to 5-lobed, deeply cut, upper leaves reduced and consisting of 3 to 4 narrow segments. Flowers yellow, 1 inch or more in diameter.

This plant was introduced from Europe and is becoming established throughout most of North America. As a rule, livestock, such as horses and cattle avoid consuming the fresh plant, thus allowing it to mature and go to seed and remain invasive. Tall Buttercup contains a bitter juice that causes inflammation and severe blistering of the mouth and intestinal tract when ingested by livestock. This plant can be found in overgrazed pastures partly because livestock find it unpalatable. Hay containing tall buttercup does not seem to cause these symptoms as the curing process tends to destroy the poisonous properties.



Tall Buttercup

- A. Plant Habit
- B. Head
- C. Achenes

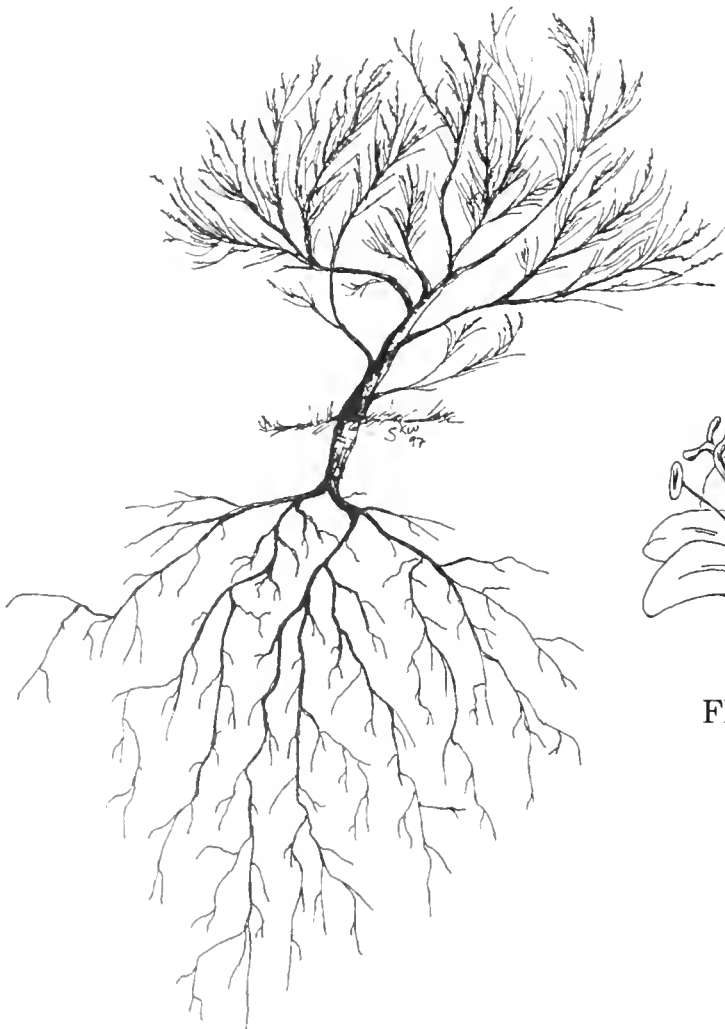
Helpful identification tips:
 Leaves are dense, hairy and have deeply lobed segments.

Saltcedar [Tamarisk] (*Tamarix ramosissima*)

Saltcedar or tamarisk is a deciduous or evergreen shrub or small tree, 5 to 20 feet tall. Bark on saplings and stems is reddish-brown. Leaves are small and scale-like, on highly-branched slender stems. Flowers are pink to white and 5-petalled.

Saltcedar was introduced to North America from the Middle East in the early 1800s. This weed has been used for ornamentals, windbreaks and erosion control. By 1850, saltcedar had escaped from these areas and infested many river systems and drainages in the southwest. By 1938, infestations of saltcedar could be found from Florida to California and as far north as Idaho. Saltcedar was first found in Montana around 1960 in Yellowstone and Big Horn River drainages.

Saltcedar is a water-loving plant. Each year, more tall, dense stands of saltcedar have the potential to use over 9 acre-feet of water for every acre of infestation. This translates to 14,520 cubic yards of water per acre of infested land. With this kind of water uptake, the total water flow along drainages with heavy infestations of saltcedar can be reduced or even eliminated.



Flower Head

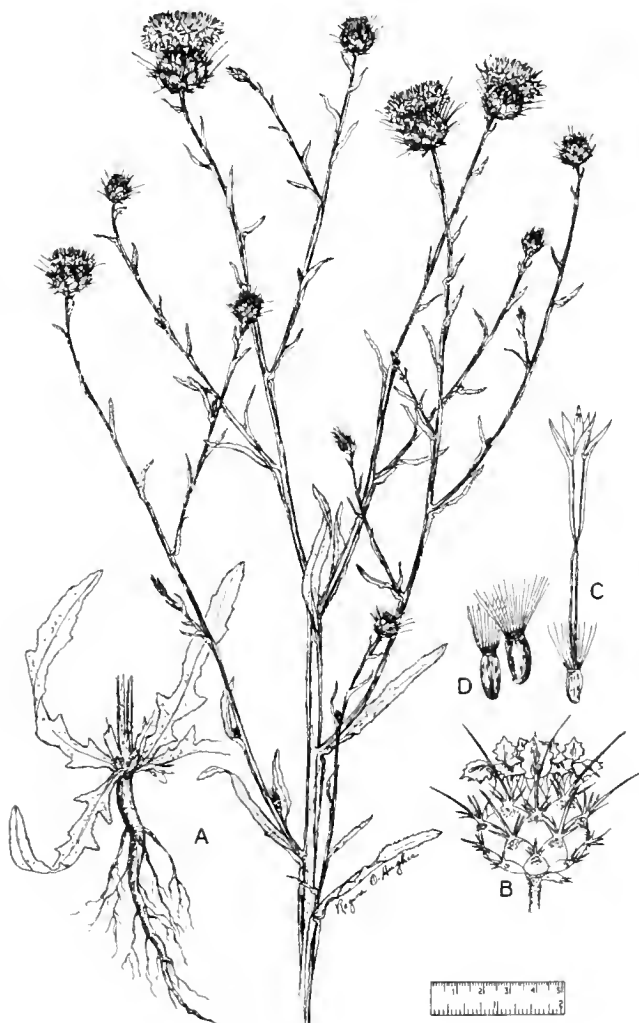
Helpful identification tips:

Flowers are pink, small 5-petalled, and borne in finger-like clusters. Leaves are scale-like, on slender, highly-branched, green stems.

Yellow Starthistle (*Centaurea solstitialis*)

Yellow starthistle is commonly a winter annual but it can germinate and grow to maturity in one season. The plant is gray green in color with cottony hair on the leaves and stems. It reaches a height of 1 to 3 feet, is branched, and has a yellow flower on the end of each branch. The leaves are narrow with the base of the leaf extending along the stem, giving them a winged or ridged appearance. The flower is bright yellow and has long sharp rigid spines as bracts below each flower. Two types of seeds are produced; light colored with bristly awns and dark with no bristles.

Yellow starthistle is found in cultivated and fallow fields, pastures, rangelands and waste places. It can invade range and pasture and competes well with existing vegetation. It crowds out existing grasses where moisture is limited and grasses are weakened from overgrazing. It produces a toxic chemical that can cause death in horses and the spines can cause serious injury to grazing animals. It has been reported in Montana in Ravalli, Lake, Gallatin, and Liberty counties. It is a serious problem in Idaho and Washington. It should be eradicated when found in Montana.



Yellow Starthistle

- A. Plant Habit
- B. Involucre
- C. Flower
- D. Achenes

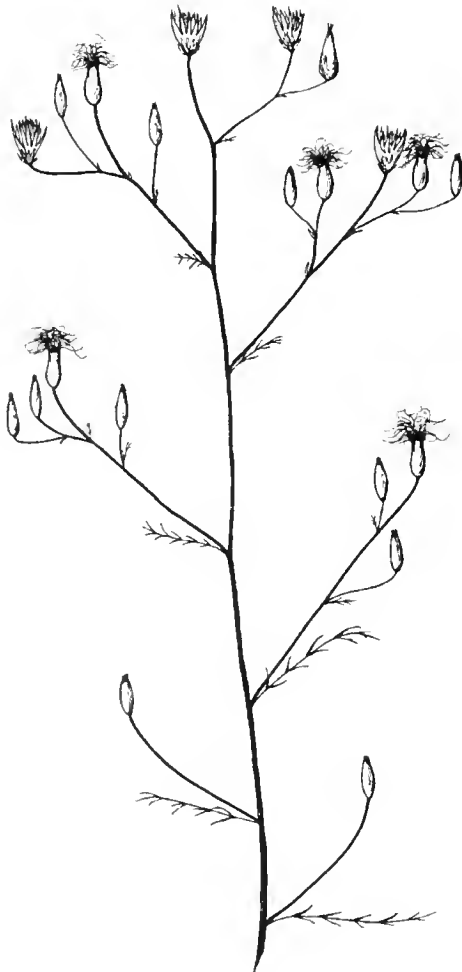
Helpful identification tip:

Yellow spines up to 3/4 inch long extend from the involucre or seed case.

Common Crupina (Crupina vulgaris)

Common crupina is a winter annual that reproduces by seed. It is closely related to the knapweed species. The cotyledon leaves are large, thick and dark green. They generally germinate in the fall when moisture is adequate and from a basal rosette. The true leaves are finely divided. A dense, fibrous root system develops quickly once the seedling is established. The plants overwinter as compact rosettes. In the spring the plant bolts and has a main flower stem from 1 to 4 feet tall. Leaves are alternate the length of the stem and are finely divided, lace-like leaflets. Stiff hairs on the leaf surface give them a sticky feel. Flowers are lavender to purple and are 1/2 inch long. Plants produce 5 to more than 100 flower heads. Each head produces 1 to 5 seeds. Seeds (achenes) are large, cylindrical, tapering slightly to a blunt end. They have a dark, stiff pappus at the basal end. Dense, fine hairs cover the seed, giving it a black to silver color.

Common crupina is generally found on well-drained, rocky to silt loam soil in pasture or rangeland. Infestations start in disturbed areas or sites with sparse vegetation. It is a recent introduction and is currently found on the federal noxious weed list. Current infestations are found only in Idaho and Washington. An effort must be made to keep this weed out of Montana.



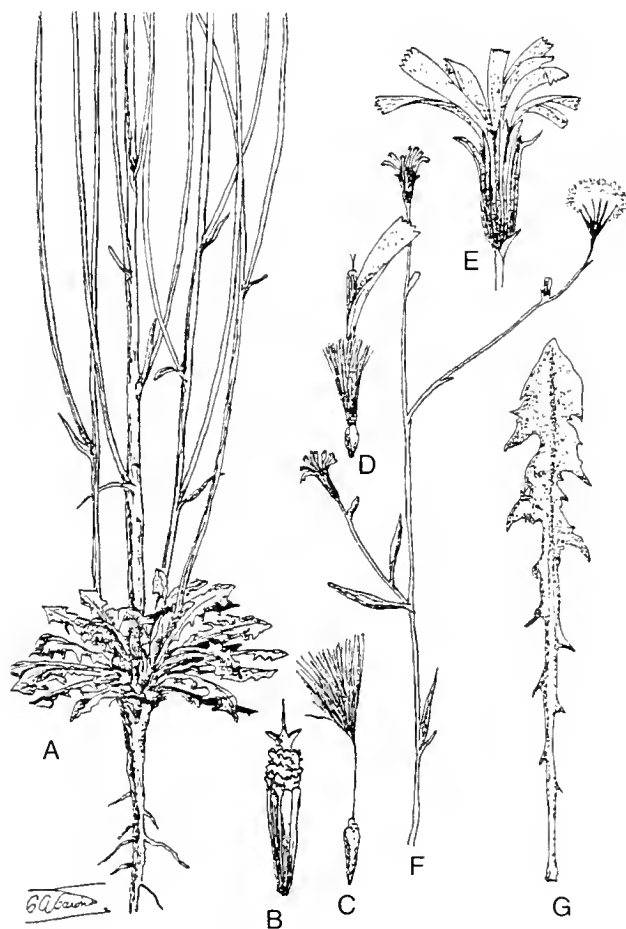
Helpful identification tip: Flower heads are narrow, cylindric and topped with pink, lavender or purple flowers.



Rush Skeletonweed (*Chondrilla juncea*)

Rush skeletonweed is a taprooted herbaceous perennial plant that overwinters as a compact rosette resembling an immature dandelion. The plant bolts in early spring and the flower stalk is 1 to 4 feet, nearly leafless with spreading side branches. Stem leaves are narrow and linear. The flowers are yellow, 3/4 of an inch in diameter, and composed of 7 to 15 individual florets. An individual plant may produce up to 20,000 seeds. Each seed is attached to a light pappus, similar to the dandelion. Seeds have no dormancy and remain viable for only 18 months under normal environmental conditions. Taproots may extend to soil depths of 7 feet and produce lateral roots which give rise to satellite plants. Cut plant surfaces exude a milky white latex sap.

Rush skeletonweed generally inhabits well-drained, light soils along roadsides, in rangelands, grain fields and pastures. Soil disturbance aids establishment. It presently infests several million acres of rangeland in Idaho, Oregon, Washington, and California. It can potentially become a problem in cropland areas with light textured soils. It has caused an estimated \$30 million loss in Australian wheat producing areas. It is not currently found in Montana and detection and eradication programs should be initiated for the state. Cooperative detection programs have been developed for the Pacific Northwest.



Rush Skeletonweed

- A. Plant Habit
- B. Seed
- C. Pappus-Bearing Seed
- D. Flowering Shoot
- E. Flower Head
- F. Flowering Plant
- G. Rosette Leaf

Helpful identification tip: Yellow flowerheads, less than one inch wide, have strap-shaped petals that are flat across the end with distinct lobes or teeth.

APPENDIX B

Common Weights and Measures

5 drops	1 cc
1 teaspoon	5 cc
3 teaspoons.....	1 tablespoon
1 tablespoon	15 cc
2 tablespoons	1 ounce
16 tablespoons	1 cup
1 cup	8 ounces
2 cups	1 pint
1 pint	16 ounces
2 pints.....	1 quart
4 quarts.....	1 gallon
1 gallon	128 fluid ounces
1 gallon.....	231 cubic inches
7.48 gallons.....	1 cubic foot
1 pound	454 grams or 16 ounces dry
1 pound	1 pint (approx.)
12 inches	1 foot
3 feet	1 yard
5.5 yards	1 rod
144 square inches	1 square foot
9 square feet	1 square yard
30 ¼ square yards.....	1 square rod
43,560 square feet.....	1 acre
4,840 square yards	1 acre
160 square rods.....	1 acre
2.471 acres	1 hectare
320 rods	1 mile
5,280 feet	1 mile
640 acres	1 section; 1 square mile

APPENDIX C

Additional Resource Materials

Biology and Management of Noxious Rangeland Weeds. 1999. Roger L. Sheley and Janet K. Petroff. Corvallis: Oregon State University Press.

Common Montana Range Plants. Montana State University Range Science Club. 2nd Edition. Robert R. Yaeger, Wayne C. Leininger, and Donald E. Ryerson.

Flora of the Pacific Northwest. 1986. The Great Plains Flora Association. Ronald L. McGregor, Coordinator. University Press of Kansas.

Herbicide Handbook, Eighth Edition. 2002. William K. Vencill. Lawrence, KS: Weed Science Society of America.

Pacific Northwest 2001 Weed Management Handbook. 2001. Ray D. William, Dan Ball, and Terry L. Miller – Oregon State University; Robert Parker, Joseph P. Yenish, and Timothy W. Miller – Washington State University; and Don W. Morishita and Pamela J.S. Hutchinson – University of Idaho. Oregon: Extension & Station Communications; Washington: Cooperative Extension; and Idaho: Agricultural Publications. Revised annually.

Poisonous Range Plants in Montana. 1977. Montana State University Cooperative Extension Service. Wayne C. Leininger, John E. Taylor, and Carl L. Wambolt.

Weed Control Manual – Volume 33. 2002. Charlotte Sine and Richard T. Meister. Willoughby, OH: Meister Publishing Company.

Weed Management Handbook – Montana, Utah, and Wyoming. 2001-2002. A. J. Bussan, Steven A. Dewey, Meghan A. Trainor, and Tom. D. Whitson. Montana: Cooperative Extension Services. Revised annually.

Weeds of Nebraska and the Great Plains. 1994. James Stubbendieck, Geir Y. Friisoe, and Margaret R. Bolick. Lincoln: Nebraska Department of Agriculture.

Weeds of the West – 9th Edition. 2000. Tom D. Whitson, Larry C. Burrill, Steven A. Dewey, David W. Cudney, B. E. Nelson, Richard D. Lee, and Robert Parker. Newark, CA: Western Society of Weed Science.

GLOSSARY

Absorption. To take in and incorporate.

Achene. A small dry, one-seeded fruit which does not split at maturity.

Acid Equivalent (ae). The amount of herbicide in a formulation when measured in its acid form that is principally responsible for the herbicidal effects and that is shown in the active ingredient statement on herbicide labels.

Acidic. Having a pH of less than 7.

Acidity. The state, quality, or degree of being acidic.

Active Ingredient (ai). The chemical(s) in a formulated product that is (are) principally responsible for the herbicidal effects and that is (are) shown as active ingredient(s) on herbicide labels.

Adjuvant. Any substance in a herbicide formulated or added to the spray solution that enhances the herbicide's effectiveness.

Adsorption. Adherence of a substance to a surface.

Agitate. To keep a mixture stirred up.

Alkali. A substance having highly basic properties; a strong base.

Alkalinity. Contains sodium and potassium carbonate salts.

Allelopathy. Suppression of plant growth by a toxin released from a nearby plant.

Annual. A plant that completes its life cycle from seed within one year.

Antagonistic. The capability of a chemical substance to interfere with the physiological action of another.

Aqueous. Relating to, similar to, containing, or dissolved in water; watery.

Axil. The area between the upper side of a leaf or stem and the supporting stem or branch.

Band or Row Application. An application to a continuous restricted area, such as in or along a crop row, rather than over the entire field.

Basal Treatment. A treatment applied to the stems of woody plants at and just above the ground.

Basic. Having a pH of more than 7.

Biennial. A plant that completes its life cycle in two years. The first year the seed germinates and the plant produces leaves, roots, and stores food. The second year it flowers and produces fruits and seeds.

Biological Control. Controlling a pest with existing or introduced natural enemies; these may already occur in the area or be introduced.

Bract. A small leaf-like structure below the flower.

Broadcast Application. A uniform application over an entire area.

Broadleaf Plants. Botanically classified as dicotyledons. Plants have two cotyledon leaves in the seedling stage; true leaves are usually broad and have netlike or reticulate veins.

Brush Control. Control of woody plants.

Cambium. Area just within the bark of woody plants with the conductive tissues (xylem and phloem).

Carrier or Diluent. A gas, liquid, or solid substance used to suspend a herbicide during its application.

Chlorosis. An abnormal condition in plants in which the green parts lose their color or turn yellow.

Compatible. Satisfactorily mixes in the spray tank for application together in the same carrier without reducing the activity of either herbicide.

Concentration. The amount of active ingredient or acid equivalent of a herbicide in a given quantity of the formulation expressed as percent or lb ai/gal.

Contact Herbicide. A herbicide that is phytotoxic or kills by contact with plant tissue rather than as a result of translocation.

Contaminate. To alter or render a material unfit by allowing the pesticide to come into contact with it.

Control. In general, reduction of the weed problem to a point where it does not cause economic damage.

Defoliant. A substance or mixture of substances used primarily to cause the leaves or foliage to drop from a plant.

Degradation. The process by which a chemical is decomposed or broken down into nontoxic compounds or elements.

Desiccant. Any substance or mixture of substances used to accelerate the drying of plant tissue.

Dicotyledon (dicot). A plant that has two seed leaves or cotyledons; broadleaf plants.

Dose (Rate). The terms are the same; however, rate is preferred. Refers to the amount of active ingredient applied to a unit area regardless of percentage of chemical in the carrier.

Drift. The movement of airborne particles or vapors away from the intended target area.

Dry Flowable (DF). Formulation made of finely ground herbicide particles compressed into granules that can be suspended readily in water for application.

Emergence. The act of germinating seedlings breaking through the soil surface.

Emulsifiable Concentrate (EC). A concentrated herbicide formulation containing organic solvents and emulsifiers to facilitate mixing with water.

Eradication. The elimination of all live plant parts and seeds of a weed from a site.

Flowable (F). Formulation made of finely ground herbicide particles that are suspended in a liquid, that is then diluted with water for application.

Foliar Application. Directing a pesticide to plant leaves or foliage.

Formulation. A mixture containing the active ingredient of a herbicide and other additives required for easy mixing and application.

GPA. Gallons per acre.

GPM. Gallons per minute.

Granular (G). A dry formulation of herbicides in which the active ingredient is impregnated on small particles of carrier such as clay or ground corn cobs. They are applied in the dry form.

Herbaceous Plant. A vascular plant that does not develop persistent woody tissue aboveground.

Herbicide. A chemical used to kill plants or severely interrupt their normal growth processes.

Hormone. A naturally occurring substance in plants that controls growth or other physiological processes. It also refers to synthetic chemicals that regulate or affect growth activity.

Inflorescence. The flowering part of the plant.

Inert Ingredient. That part of a formulation without toxic or killing properties.

Inhibit. To hold in check or stop.

Integrated Control. Decision-based approaches for pest control using pesticides when necessary and at appropriate rates.

Involucre. A circle of bracts under a flower cluster.

Leaching. The downward movement of a substance in solution through the soil.

Monocotyledon (monocot). A seed plant having a single cotyledon or leaf; includes grasses, sedges, and lilies.

Necrosis. Dead tissue.

Nonselective Herbicide. A chemical that is generally toxic to plants without regard to species.

Noxious Weed. A weed specified by law as being especially undesirable, troublesome, and difficult to control.

Perennial. A plant that lives for more than two years.

Pesticide. Any substance or mixture of substances that controls or kills insects, rodents, weeds, fungi, and other pests.

Phloem. Vascular system in plants that transports sugars.

Photosynthesis. Plant process converting carbon dioxide and water into sugar, using energy from sunlight.

Phytotoxic. Injurious or toxic to plants.

Postemergence. After emergence of the specified weed or planted crop.

Postharvest. Application of a pesticide to the soil or plant after crops have been harvested.

Preemergence. Prior to the emergence of the specified weed or planted crop.

psi. Pounds per square inch.

Receptacle. The part of the stem to which the flower is attached.

Registered. Pesticides approved for use in Montana by the Montana Department of Agriculture.

Residual. To have continued killing effect over a period of time.

Resistant. Acquired trait that allows a plant to survive herbicide treatment that typically controls that species. Survival is not due to stress conditions or application.

Rhizome. Underground rootlike stem that produces roots and leafy shoots.

Rosette. Compact cluster of leaves often arranged in a basal circle.

Seedling Stage. Early stage of plant growth, within a few days to a few weeks after seed germination and emergence.

Selective Herbicide. A chemical that is toxic to some plant species and not to others.

Silicle. A short silique, almost equally as long as wide.

Silique. Elongated capsule with a septum separating in two valves.

Soil Persistence. Refers to the length of time that a herbicide remains effective in the soil.

Soil Sterilant. A herbicide that prevents the growth of plants when present in the soil.

Solubility. The amount of a substance that will dissolve in a given amount of liquid.

Solvent. A liquid, such as water or oil used to dissolve other materials, such as herbicides.

Spot Treatment. Application to a localized area.

Spreading Agent. A substance to improve wetting, spreading, or the adhesive properties of a spray.

Stolon. Aboveground runners or slender stems that develop roots, shoots, and new plants at tips or nodes.

Suppression. Reduction of weed population, but not elimination.

Surface tension. Surface molecular forces that cause a drop or liquid to ball up rather than spread out as a film.

Surfactant. A material that favors or improves the emulsifying, dispersing, spreading, wetting, or other surface modifying properties of liquids.

Susceptible. A plant that is injured or killed because it is unable to tolerate herbicide treatment.

Suspension. Liquid containing dispersed, finely divided particles.

Synergistic. Producing or capable of producing synergy.

Synergy. The interaction of two or more agents or forces so that their combined effect is greater than the sum of their individual effects.

Systemic. A compound that moves freely within a plant; application to one area results in movement to all plant areas.

Tolerant. A plant species that normally survives herbicide treatment without injury.

Translocated Herbicide. A herbicide that moves within a plant.

Translocation. Transfer of sugars or other materials such as 2,4-D from one part to another in plants.

Vapor Drift. The movement of chemical vapors from the area of application.

Vaporize. To change from liquid to a gas.

Volatile. A compound that evaporates or vaporizes at ordinary temperatures when exposed to air.

Weed. A plant growing where it is not desired. Any plant that is a nuisance, hazard, or causes injury to humans, animals, or crops.

Wettable Powder (WP). A finely ground, dry herbicide formulation that can be suspended readily in water.

Wetting Agent. An adjuvant that reduces interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces.

Xylem. Vascular tissue in plants that transports water.

REFERENCES

- Ahrens, William H. 1994. *Herbicide Handbook – Seventh Edition*, Weed Science Society of America, Champaign, IL.
- Gardner, Ronald D. and Eric P. Harrington. 1991. *Pesticide Applicator Training Manual – Right-of-Way Pest Control*, Cornell University, Ithaca, NY.
- Hitchcock, C. Leo and Arthur Cronquist. 1973. *Flora of the Pacific Northwest*, University of Washington Press, Seattle and London.
- Lembi, Carole A. and Merrill A. Ross. 1985. *Applied Weed Science*, Burgess Publishing Company, Minneapolis, MN.
- Marer, Patrick J., Mark Grimes, and Richard Cromwell. 1995. *Forest and Right-of-Way Pest Control*, University of California.
- Muenschner, Walter Conrad. 1955. *Weeds – Second Edition*, Cornell University Press, Ithaca, NY.
- Oregon State University, University of Idaho, Washington State University. 1998. *Pacific Northwest Weed Control Handbook*, Oregon State University.
- Ramsay, Carol A. and Robert Parker. 2001. *Rights-of-Way Vegetation Management*, Washington State University Cooperative Extension.
- Stubbendieck, James. 1994. *Weeds of Nebraska and the Great Plains*, Nebraska Department of Agriculture, Lincoln, NE.
- Whitson, Tom D. et. al. 2000. *Weeds of the West*, The Western Society of Weed Science, Newark, CA.

ANSWERS TO REVIEW QUESTIONS

General Weed Control – Answers

1. d
2. c
3. d
4. b
5. a
6. d
7. b
8. a
9. a
10. b
11. b
12. a

Right-of-Way – Answers

1. a
2. b
3. d
4. a
5. b
6. c
7. a
8. b
9. d
10. a
11. a

Applying Herbicides Safely and Accurately – Answers

1. b
2. d
3. a
4. a
5. b (add a lightweight emulsifiable oil to protect the tank, pump, and plumbing)
6. a
7. a. 38.9 – 43.1 ounces
 $245 \div 6 = 40.8$ then round to 41 ounces. 10% error is 4.1 then divide by 2 = 5% error of 2.05 (round to 2.1). Add 2.1 to 41 = 43.1; subtract 2.1 from 41 = 38.9
8. d. 18.1 GPA
 $3000 \text{ ft}^2 \div 43,560 \text{ ft}^2 = 0.0689 \text{ ft}^2$ [0.068870523 ft^2 , then round up to 0.0689 ft^2]
 $1.25 \text{ gallons} \div 0.0689 \text{ ft}^2 = 18.1 \text{ GPA}$
9. b. 13.8 acres
 $250 \text{ gallons} \div 18.1 \text{ acres} = 13.8 \text{ acres}$
10. a. 2 gallons
 $1 \text{ pint} \times 16 \text{ acres} = 16 \text{ pints} \div 8 \text{ pints} = 2 \text{ gallons}$
 $8 \text{ pints} = 1 \text{ gallon}$

300 copies of this public document were published at an estimated cost of \$9.00 per copy, for a total cost of \$2,700.00, which includes \$2,700.00 for printing and \$.00 for distribution.